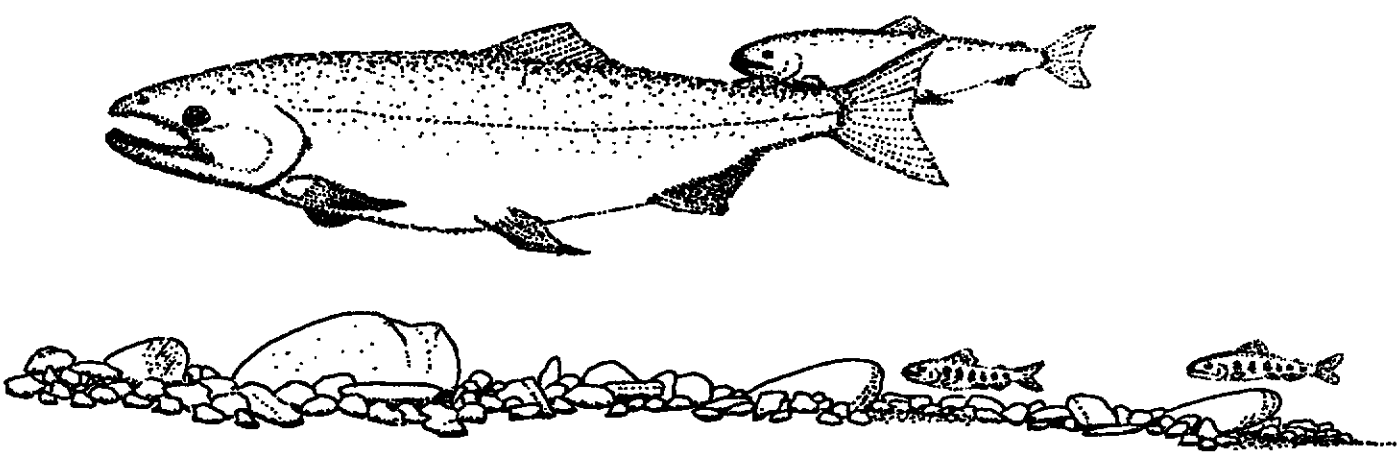
U.S. DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

THE EFFECTS OF FRY SUPPLEMENTATION ON THE EMIGRATION OF SALMONIDS FROM TRIBUTARIES OF THE CLEARWATER RIVER, WASHINGTON



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The Effects of Fry Supplementation on the Emigration of Salmonids from Tributaries of the Clearwater River, Washington

by

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ABSTRACT

We evaluated the emigration behavior of hatchery-reared coho fry, obtained from a native broodstock, stocked in small streams to supplement wild coho salmon populations and the effect of these stocked fish on the emigration behavior of wild coho fry and native trout. Total emigration of wild coho fry and cutthroat trout was not increased in streams supplemented with hatchery-reared coho fry (0.6-1.0 g). However, the relationship between total emigration of wild coho fry and cutthroat trout and June rearing densities of these species was different in supplemented and control streams. Wild coho fry and juvenile steelhead emigrated earlier in supplemented streams than those in control streams, while cutthroat trout emigration appeared to be delayed. Between 9.3% and 46.9% of stocked hatchery-reared coho fry emigrated from supplemented streams. Hatchery-reared coho fry emigrated earlier than wild coho fry and were less likely to rear in downstream habitat than wild coho fry. The magnitude and early timing of hatchery-reared coho fry emigration and potential impacts of stocking hatchery-reared coho fry on wild coho fry emigration may inhibit supplementation programs from successfully increasing total coho salmon densities in streams.

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INTRODUCTION

Wild coho salmon (*Oncorhynchus kisutch*) populations in the Pacific Northwest have declined over the last decade, some to critically low levels (Nehlsen et al. 1991). Reductions in abundance have reduced or restricted fisheries and threatened the loss of genetic variability (Helle 1984). Supplementation may provide a method to address this problem (Nickelson et al. 1986, Wampler et al. 1990), but, few detailed studies evaluating supplementation exist (Steward and Bjornn 1990; Wunderlich and Pantaleo 1995). There is concern that supplementation using non-native hatchery stocks could negatively affect genetic and ecological characteristics of native stocks as well as reduce their productivity (Steward and Bjornn 1990). Genetic and ecological effects stem largely from transfer of genetic characteristics from hatchery stocks to wild stocks potentially resulting in maladapted behavior. Progeny of hatchery fish and those produced by wild and hatchery matings often display reduced survival compared to wild progeny (Reisenbichler and McIntyre 1977; Chilcote et al. 1986; Nickelson et al. 1986; Leider et al. 1990). Maladaptive traits which negatively influence survival of hatchery fish and hatchery:wild offspring include early run timing (Nickelson et al. 1986), reduced disease resistance (Buchanan et al. 1983; Hemmingsen et al. 1986), altered behavior (Fenderson et al. 1968; Swain and Riddell 1990), and reduced foraging efficiency (Sosiak et al. 1979; Bachman 1984; Irvine and Bailey 1992).

To avoid the problems associated with using non-native hatchery stocks, the Washington Department of Fisheries, Quinault Indian Nation, and the U.S. Fish and Wildlife Service developed a native broodstock for supplementation activities in the Clearwater basin (Quinault Indian Nation 1992). Adults captured from the mainstem Clearwater River and its tributaries were spawned and reared in a hatchery to the smolt stage. Smolts were released from a collection facility located in the Clearwater basin (Figure 1). Wild coho salmon have been taken from the mainstem Clearwater River and its tributaries and incorporated into this broodstock each year to help maintain the genetic integrity of the brood (Quinault Indian Nation 1992).

Fry supplementation can reduce native stock productivity at the time of planting mainly through competition for food and space resulting in emigration and/or mortality of native salmonids (Steward and Bjornn 1990). Hatchery coho salmon fry stocked in Oregon coastal streams replaced 44% of wild coho salmon, apparently as a result of the competitive advantage resulting from the larger size of hatchery fish at stocking (Nickelson et al. 1986). The mode of replacement, mortality or emigration, was not determined. Introductions of hatchery-reared coho salmon resulted in shifts in microhabitat use and foraging behavior and caused a greater rate of downstream movement in wild coho salmon (Nielsen 1994). Hatchery coho salmon in Nielsen's (1994) study originated from both hatchery and wild broodstocks.

Studies examining the effect of stocked hatchery salmonids on the displacement or emigration of wild salmonids have given mixed results. Stocking catchable sized rainbow trout (*O. mykiss*) did not affect wild rainbow or cutthroat trout (*O. clarki*) except at the highest stocking rates, when effects were limited (Petrosky and Bjornn 1988). Stocked catchable rainbow trout used different habitat than wild steelhead trout (< 200 mm) and no aggressive interactions were observed between the two groups (Hillman and Chapman 1989). Stocked catchable size brown trout (*Salmo trutta*) displaced wild brown trout but then failed to return to foraging sites after aggressive interactions or foraging forays (Bachman 1984). Catchable size rainbow trout stocked into streams have displaced juvenile steelhead trout, assumed their foraging stations (Pollard and Bjornn 1973) and caused accelerated movements of 2-year-old and older wild brown trout (Vincent 1987).

Studies evaluating the effect of stocking zero age salmonids on the emigration of wild salmonids also have given mixed results. Stocked age 0+ Atlantic salmon (*S. salar*) used different habitat than resident rainbow trout fry and did not affect their movements (Hearn and Kynard 1986). Juvenile chinook salmon (*O. tshawytscha*) occupied different habitats following stocking of hatchery coho salmon; however, emigration of juvenile chinook and steelhead was not noticeably increased (Spaulding et al. 1989). "Thinning" releases (releases designed to decrease densities in hatchery ponds) of hatchery steelhead (age 0) did not cause wild chinook or steelhead to emigrate (Hillman and Mullan 1989). In contrast, "thinning" releases of hatchery chinook salmon caused 38-78% of wild chinook salmon and 15-45% of wild steelhead to emigrate (Hillman and Mullan 1989). Hillman and Mullan (1989) speculated that the migration pattern of the hatchery chinook salmon, rather than competition, caused the emigration of wild chinook salmon and steelhead. Released chinook salmon migrated downstream, taking up temporary feeding stations.

The main objective of this study was to evaluate the effect of stocking small streams with hatchery-reared coho salmon fry (obtained from a native broodstock) on the emigration of wild coho fry and native trout. Specifically, we wanted to determine whether stocking hatchery-reared, wild coho fry increased the rate or magnitude of emigration by wild coho fry and native trout. I also wished to determine whether wild and hatchery-reared coho fry exhibited different emigration timing. Finally, the fate of emigrating wild and hatchery-reared coho salmon fry was examined to determine whether emigrating wild coho fry were more likely to take up residence in habitats downstream.

Study Area

This study was conducted in six small tributaries of the Clearwater River, Washington (Figure 1). These streams were selected based on personal examination and on recommendations from Quinault Indian Nation fisheries personnel. The primary selection criteria were that wild coho salmon were known to use the stream and that stream size was amenable to the installation and operation of weir style fry traps. Bull, Prairie, Peterson, 0042, Elkhorn, and Hunt creeks were selected based on these criteria (Table 1). Mainstem and wall-base channel habitats sampled during the summer and winter to determine the fate and distribution of emigrating wild and hatchery coho fry have been described previously (Chapter IV).

Table 1. Summary of stream conditions.

Stream	Length (km)	Stream Order	Discharge (cfs)[a]	Gradient (%)	Approx. Basin Area (km^2)	Canopy
Bull	4.0	2	1.00	1-2	6[b]	Alder, Spruce, Salmon berry
Prairie	2.4	2	0.60	4-6	3	Salmon Berry, Hemlock, Alder, Spruce
Peterson	3.7	1	0.08	1-2	3[c]	Salmon Berry, Alder, Spruce, Hemlock
0042	1.0	2	0.30	2-4	3	Alder, Salmon Berry, Hemlock
Elkhorn	3.1	1	0.30	2-5	3[c]	Alder, Salmon Berry, Hemlock
Hunt	3.7	2-3	0.35	3-5	5	Alder, Salmon Berry, Hemlock

[a]Quinault Indian Nation, Department of Natural Resources (Unpublished data), low flow data
[b]Winter and Wampler (1980)
[c]Cederholm and Scarlett (1982)

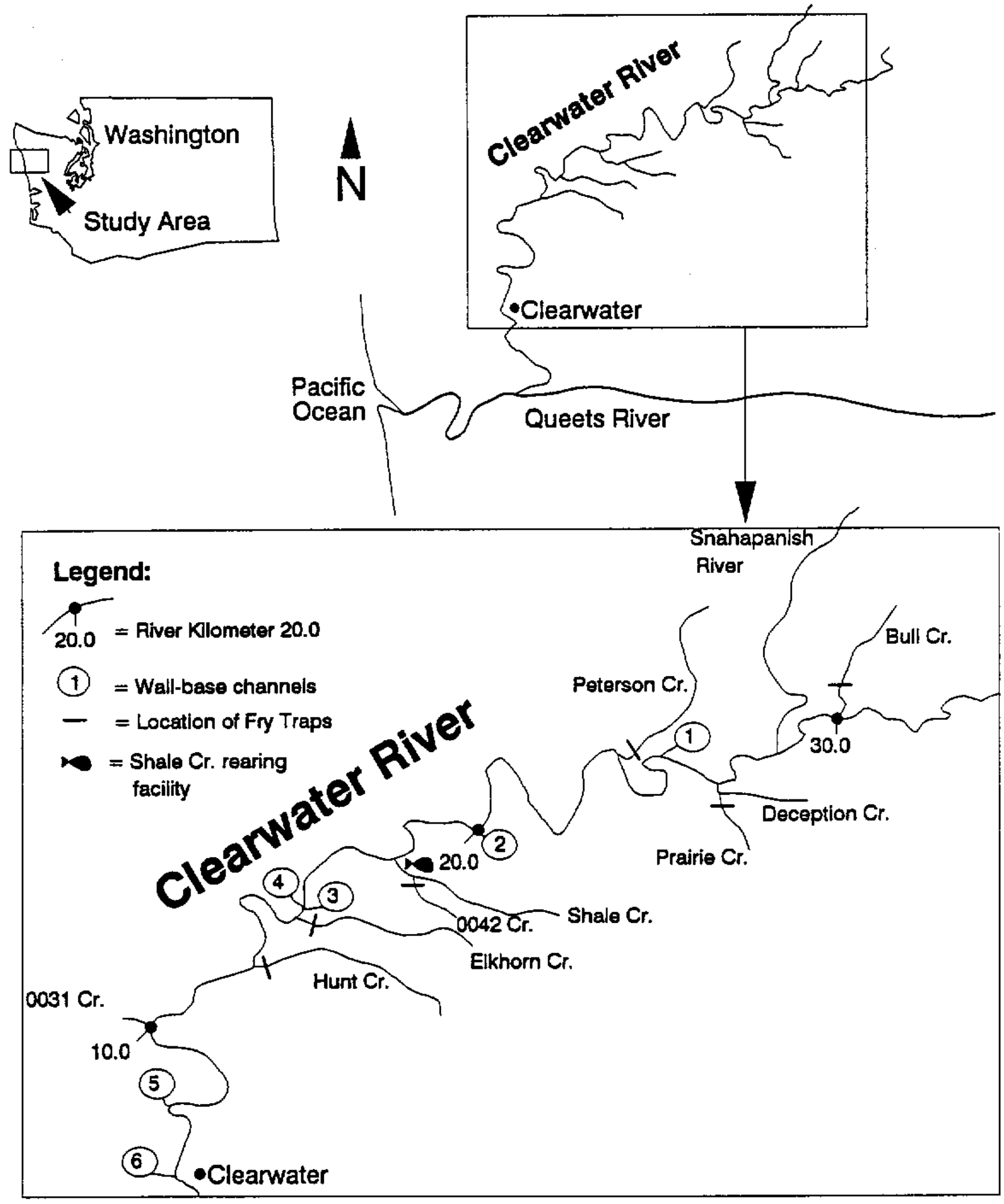

Figure 1. **Location of study streams in the Clearwater River basin. Wall-base channels monitored include (1) Coppermine Bottom Pond, (2) Pond 2, (3) Paradise Pond, (4) Swamp Creek Beaded Channel, (5) Airport Pond, and (6) Morrison Pond.**

MATERIALS AND METHODS

The effect of fry supplementation on the emigration of native salmonids was evaluated in six tributaries of the Clearwater River over a 3-year period. Three randomly selected streams were stocked (Bull, 0042, Hunt) during the spring of 1991 with hatchery-reared coho salmon fry obtained from a native broodstock (Quinault Indian Nation 1992). The three remaining streams were not stocked and served as controls (Peterson, Prairie, Elkhorn) for 1991. Treatments and controls were reversed during the spring of 1992, with streams stocked in 1991 serving as controls during 1992, while 1991 control streams were stocked in 1992. Emigration data also were collected from all six streams during 1993 when no stocking occurred (controls). Fry traps were installed in each stream prior to stocking to monitor downstream movement of hatchery-reared and wild coho fry, coho smolts, and native trout.

Coho salmon fry used to stock supplemented streams were obtained from a native broodstock developed by the Quinault Indian Nation, Washington Department of Fisheries, and U.S. Fish and Wildlife Service (Quinault Indian Nation 1992). The broodstock was developed by capturing wild coho salmon from the Clearwater River, beginning in 1984, and rearing their progeny to smolts before release (Quinault Indian Nation 1992). The release site of smolts and the location of most adult collection is the Washington Department of Fish and Wildlife Shale Creek Hatchery located within the Clearwater River basin (Figure 1.1). Wild spawners from the mainstem and its tributaries have been collected each year and infused back into the broodstock population to maintain genetic characteristics.

Broodstock collection for the spring 1991 fry stocking occurred during the fall of 1990. One hundred Shale Creek females and 46 wild Clearwater females were spawned with Shale Creek males (Quinault Indian Nation 1992). The progeny were reared at the Quinault Tribe's Lake Quinault Hatchery until May when they were released (Table 2). Nearly all hatchery-reared fry were adipose fin clipped and coded wire tagged with a unique code for each stream (Table 2).

No Shale Creek broodstock was available during the 1991 brood year due to a 1990 Viral Hemorrhagic Septicemia Virus (VHSV) outbreak at the Soleduck Hatchery, the original incubation site for the Clearwater River eggs (Quinault Indian Nation 1992). This resulted in the loss of nearly all the 1988 broodyear release from Shale Creek and all of the progeny from the 1989 brood year. Thus, only wild coho salmon from the Clearwater River were used for the broodstock during 1991. Fry were the progeny of 37 males and 31 females. VHSV was isolated in the ovarian fluid of one of these females. Fortunately, eggs were incubated in five-fish lots, each with a separate water source, allowing the VHSV-positive lot to be culled to prevent contamination of other lots. The remaining egg take was isolated during incubation and early rearing and the effluent treated. Routine testing of the remaining eggs showed no other VHSV contamination. Tagging was completed at the Shale Creek facility within the Clearwater River Watershed. Net pens were constructed to keep the different tag groups (by stream) of fry separate during the tagging procedure. However, the mesh size was too large and fry escaped and intermingled, eliminating the ability to identify the hatchery-reared fry stocked into the different supplemented streams following emigration and distribution throughout the basin (Quinault Indian Nation 1993).

Fry (0.6-1.1 g) were stocked in early May during both 1991 and 1992 (Table 2). A tanker truck was used to transport fry to the stream vicinity. Fry were then transferred to buckets containing plastic bags, which were filled with oxygen and tied shut to provide oxygen during transportation. The buckets were carried upstream and fry released into each pool at an approximate density of 3 fry/m² pool area until all fry had been released (Table 2).

Table 2. Total number of hatchery-reared coho salmon fry released into test streams during 1991-1992 (adapted from Quinault Indian Nation 1992, 1993).

Stream	Release Date	Nominal Release	Actual Release	Ad. Marked (%)	Tagged (%)	Actual Density (fry/m²)[a]	Size at Release (g)
			1991				
Bull	3 May 1991	10,000	9,701	99	81.2	2.2	1.1
Hunt	2 May 1991	10,000	9,360	98	74.5	2.4	1.0
0042	2 May 1991	3,600	3,897	97	78.0	3.0	1.1
			1992				
Prairie	2 May 1992	2,200	1,709	94	56.9	2.3	0.6
Peterson	2 May 1992	3,600	3,423	94	56.9	2.8	0.6
Elkhorn	1 May 1992	2,000	1,259	94	56.9	1.9	0.6

[a]based on habitat measurements taken at summer low flow the year before planting.

Downstream migrant traps were installed in each stream (Figure 1.1) prior to stocking of hatchery-reared coho salmon fry to monitor the downstream migration of hatchery-reared and wild coho salmon fry, coho smolts, and native trout. Traps were installed as soon as the water level dropped to a workable level in early spring (March-April) and were operated through mid to late August (Appendix A). The traps were v-weirs constructed with wood-framed wings which supported 0.64-cm hardware cloth. The wings forced the fish to the center of the 'v' where a 10-cm plastic pipe entered the weir and extended downstream to a wood-framed live box. Mid-stream wings had framed "pop-outs" which could be removed during periods of high flow to protect the trap from damage. Traps were checked daily during periods of intensive migration and every other day during periods of less intense migration. All species were enumerated with a sample of each salmonid species weighed (nearest g) and measured for fork length (nearest mm). In 1991 wild and hatchery-reared coho salmon fry were marked using carbon dioxide freeze branding (Bryant and Walkotten 1980) with a brand unique to that stream to allow for identification later in the summer. Once all data had been recorded, fish were released downstream of the trap to continue their migration.

Total emigration of wild and hatchery-reared coho salmon fry was estimated by summing the total number trapped, the estimated number eaten by coho smolts, cutthroat trout, and steelhead trout while in the live box, and the estimated number of fish migrating past the trap while it was not fishing. Some coho salmon fry were consumed in the live box even though screens were installed to keep fry separate from larger salmonids. Coho smolts, cutthroat trout, and steelhead trout removed from the live box were given a fullness index of "full" or "not full", based on the protrusion of their stomachs. Coho salmon fry were extracted from a sample of coho smolts, cutthroat trout, and steelhead trout of different lengths using pulsed gastric irrigation (Foster 1977). It was assumed that all coho fry which appeared to be little digested were consumed in the live box. This information was used to develop a regression equation relating numbers of fry consumed by length of predator, to fish of both fullness indices, to estimate the number of coho salmon fry eaten by the unsampled portion of each species (Appendix B). All predator species were combined to develop this regression equation, since sample sizes were insufficient to obtain meaningful results for each predator species individually. The numbers of wild and hatchery-reared coho salmon fry consumed were calculated based on the proportion of each type of fry in that day's catch. This calculation assumes that wild and hatchery-reared coho salmon fry were equally susceptible to predation in the live box. The number of salmonids migrating each day the trap was not fishing was estimated by averaging the catch during the last day the trap fished properly and the first catch after the trap resumed fishing. Estimates of total emigration of coho smolts, cutthroat, and steelhead were obtained using these same methods, with the exception that no estimate of consumption in the trap was developed. None of these species were observed in stomach samples of predatory fish.

Effect of Coho Fry Supplementation on Total Coho Fry and Cutthroat Emigration

The effect of fry supplementation on the total number of wild coho salmon and cutthroat trout emigrating from streams was examined by comparing the estimated number of emigrants of each species from control and supplemented streams. An ANCOVA was used to compare the mean numbers of emigrants and the relationship between total numbers of emigrants and observed rearing densities (fish/m^2 pool) of each species in supplemented and control streams during June. The ANCOVA for coho salmon was completed using both wild coho fry densities only and combined wild and hatchery coho fry densities as the covariate.

Effect of Coho Fry Supplementation on Salmonid Emigration Rates

The effect of stocking hatchery-reared coho salmon fry on the emigration rate of wild coho salmon fry, cutthroat trout, steelhead trout, and wild coho salmon smolts was evaluated among supplemented and control streams using a Kolmogorov-Smirnov goodness of fit test for continuous data (KS test). The migration rates of hatchery and wild coho salmon (fry and smolts) from supplemented streams also were compared using a KS test. These tests were completed for data collected during 1991 and 1992 separately and combined, (1992 and 1993 for hatchery and wild smolts), using emigration data obtained from the time hatchery fry were stocked to the end of the trapping season. One exception was for the evaluation of hatchery and wild coho smolts emigration rates, which was completed using data for the entire trapping season (included data collected prior to stocking hatchery fry).

Daily catch data (numbers of emigrants) for each species were transformed to percent of total emigration (daily) by dividing the number of emigrants caught each day by the total number of fish of each species estimated to have emigrated from the stream (see above section). Cumulative percent emigration for each species was then calculated for each trapping day by adding the daily percents from each successive day to the cumulative percent up to that day. The mean cumulative percent for control and supplemented streams (overall effect of supplementation on emigration) and hatchery and wild coho fry and smolts from supplemented streams (comparison of hatchery and wild emigration rates) were calculated and compared using a KS test (Zar 1984). This procedure was used to compare emigration rates of each salmonid species (coho fry (wild and hatchery), coho smolts (wild and hatchery), cutthroat, steelhead) sampled while trapping.

Effect of Coho Fry Supplementation on Lengths of Emigrating Salmonids

The effect of stocking hatchery-reared coho salmon on the length of emigrating wild coho salmon fry was examined using two different methods. First, the average length of wild coho salmon emigrating the day prior to stocking hatchery-reared coho salmon in supplemented streams was compared to the average length of wild coho salmon emigrating the day following stocking in these streams using a standard t-test. Second, the lengths of wild coho fry emigrating from control versus supplemented streams, from the time hatchery-reared coho fry were stocked until trapping was terminated was compared using an ANCOVA. The date when lengths were recorded was included in the ANCOVA as the covariate. The ANCOVA was used to determine whether the average lengths of emigrating wild coho fry were significantly different in control and supplemented streams and whether lengths of emigrating wild coho fry changed differently over time in supplemented than in control streams. Only data from 1991 were used for this comparison because insufficient data were available for statistical analysis during 1992.

The lengths of wild and hatchery coho fry emigrating from within each supplemented streams during 1991 and 1992 also were compared using an ANCOVA. This analysis included only data from the date when hatchery fry were stocked through the last day when both hatchery and wild coho fry were represented in the catch. This eliminated the potential bias from different growing periods available to emigrating fry, which would occur if one group ceased emigrating before the other.

A two-way ANOVA was used to compare the length of wild coho salmon smolts emigrating from supplemented and control streams the year following stocking (e.g., stocked 1991, comparison of smolt size in 1992). It was assumed that growth of coho smolts during the emigration period would be negligible. Therefore, comparisons of wild coho smolt lengths were completed using data collected during the entire smolt emigration period without controlling for timing (date). Treatment (control and supplemented) and year (1992 and 1993) were included as the two factors in the two-way ANOVA and the interaction between these two factors was examined. Lengths of wild and hatchery coho smolts emigrating from each supplemented stream during 1992 and 1993 were compared using a standard t-test.

Fate of Emigrating Coho Salmon

An effort was made to determine the subsequent fate of emigrating coho salmon fry freeze branded prior to release from the traps in 1991. We sampled downstream of the fry traps in Bull Creek, Peterson Creek, 0042 Creek, and Elkhorn Creek to their confluence with the mainstem during mid-summer, using electrofishing. Since 0042 is a tributary to Shale Creek, we also sampled Shale Creek to its confluence with the mainstem Clearwater River. We did not sample downstream of the traps in Hunt Creek because there is little distance between the trap and the confluence with the mainstem, and in Prairie Creek (too few fry were branded there). We also sampled areas in the mainstem downstream of each study stream's confluence during July and September. Beach and purse seines were used to catch coho salmon near woody debris accumulation in the mainstem (Chapter IV). We also examined fry as they moved into wall-base channels during the fall (Chapter IV). All fry were anesthetized, examined for brands with a sub-sample being weighed (g) and measured for fork length (mm) as described above and released into the habitat from which they had been taken.

RESULTS

Effects of Coho Fry Supplementation on Coho Fry and Cutthroat Emigration

Total emigration of hatchery-reared coho salmon stocked into supplemented streams was quite variable (Table 3). Between 9.3% and 46.9% of hatchery-reared coho fry emigrated from supplemented streams. The percent of hatchery fry stocked into supplemented streams emigrating from that stream was greater (t-test: $P=0.0139$) in 1991 (mean = 34.6%) than 1992 (mean = 14.8%). Estimated densities that emigrating hatchery-reared coho fry would have produced in upstream habitat during late August ranged from 0.56 to 3.07 fry/ m^2 pool area. Daily emigration patterns of hatchery-reared coho fry are displayed in Figures C.1-C.2 in Appendix C.

Total numbers of wild coho fry actually caught and estimated to have emigrated from control and supplemented streams varied between streams and years (Table 4). Actual and estimated emigration was greatest during 1991 and declined during the next three years. Daily emigration patterns of wild coho fry are displayed graphically in Figures C.1-C.3 in Appendix C.

Table 3. Total number of hatchery-reared coho salmon fry caught in fry traps, estimates of total migration, and the percent of stocked hatchery-reared coho salmon emigrating during 1991-1992.

	Actual catch		Estimated migrants		Percent emigration	
Stream	1991	1992	1991	1992	1991	1992
Bull	3,691	----	4,549	----	46.9	----
Prairie	----	156	----	193	----	11.3
Peterson	----	766	----	815	----	23.8
0042	1,473	----	1,594	----	40.9	----
Elkhorn	----	98	----	117	----	9.29
Hunt	1,287	----	1,507	----	16.1	----

Table 4. Total number of wild coho fry caught in fry traps and estimates of total emigration during 1991-1993.

	Actual catch			Estimated migrants		
Stream	1991	1992	1993	1991	1992	1993
Bull	1,652	773	72	2,167	1,352	321
Prairie	64	18	0	86	147	0
Peterson	3,174	402	4	3,559	839	5
0042	3,290	2	98	3,795	2	129
Elkhorn	3,049	167	753	3,187	307	892
Hunt	1,404	31	127	1,507	485	287

Mean total emigration of wild coho salmon was not increased in supplemented streams as compared to control streams during 1991 and 1992 (Table 5). However, the relationship between the number of emigrating coho salmon and June rearing densities (fish/m^2 pool area) was different in supplemented and control streams (Figure 2), although the difference was not statistically significant (Table 5). The estimated number of emigrants in control streams was low when observed densities were low and increased as observed densities increased. In contrast, estimated numbers of emigrants were high when observed densities were low and decreased as observed densities increased. The relationship was the same whether only wild coho or combined wild and hatchery-reared coho fry densities were used (Figure 2).

Actual and estimated numbers of emigrating cutthroat trout were relatively consistent among streams and years (Table 6) compared to coho fry emigration (Table 4). Daily emigration patterns of cutthroat trout are displayed graphically in Appendix Figures C.4-C.6.

Mean total emigration of cutthroat trout was not increased in supplemented streams as compared to control streams during 1991 and 1992 (Table 5). However, the relationship between estimated numbers of emigrants and observed rearing densities (fish/m^2 pool) during June was different in control and supplemented streams (Figure 3), although the difference was not statistically significant (Table 5). Estimated numbers of cutthroat emigrants did not change with increasing cutthroat densities in control streams (Figure 3). In contrast, the estimated number of cutthroat emigrants increased with increasing cutthroat densities in supplemented streams (Figure 3).

Table 5. Mean estimated emigration of wild coho fry and cutthroat trout in supplemented and control streams and results of the ANCOVA comparing these means among control and supplemented streams and the relationship of estimated numbers of emigrants with observed densities during June in control and supplemented streams during 1991 and 1992.

Species	Mean (SD) number of emigrants		Results (*P*) of ANCOVA comparison	
	Control	Supplemented	Means	Relationship (emigrants vs. density)
Coho	1445.2 (1572.5)	1460.3 (1370.6)	0.1485[a]/ 0.2122[b]	0.1332[a]/ 0.1245[b]
Cutthroat	166.7 (70.2)	210.8 (73.6)	0.8605	0.4113

[a]Results calculated using observed densities of wild coho salmon only

[b]Results calculated using observed combined wild and hatchery-reared coho fry densities

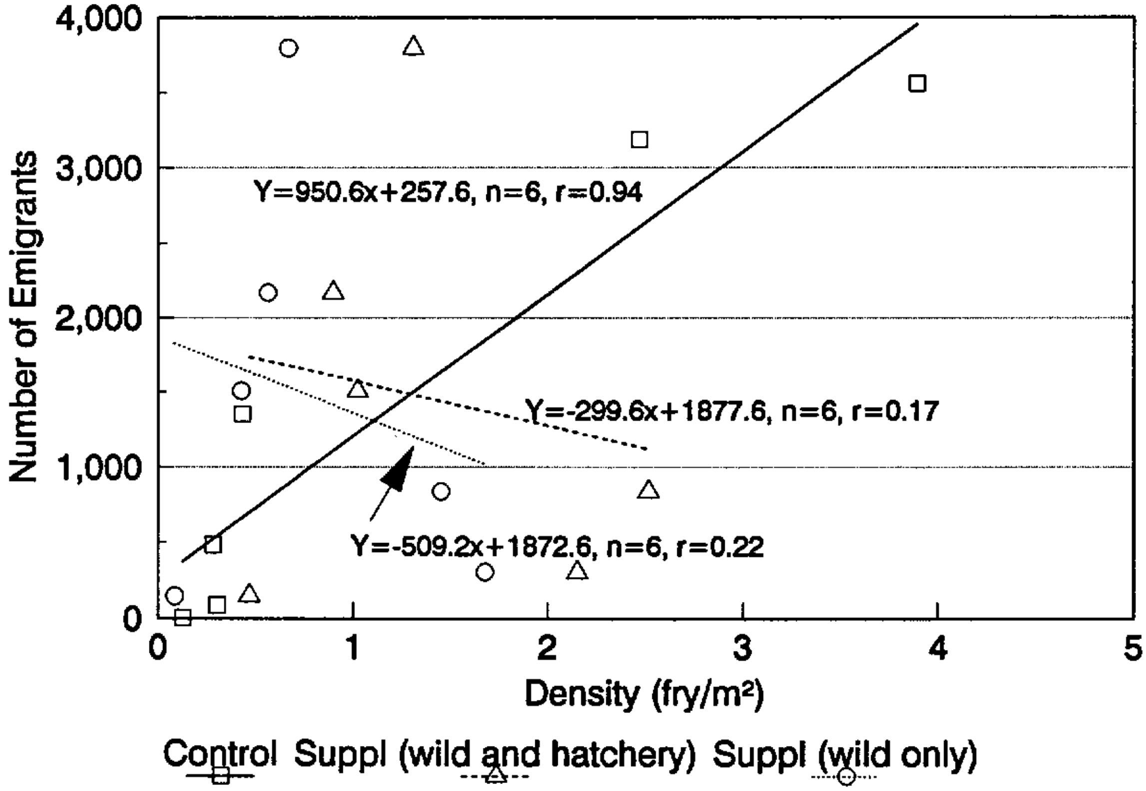

Figure 2. Relationship between coho salmon fry rearing densities (fish/m^2 pool area) during June (Peters 1996) in supplemented (wild only and wild and hatchery combined) and control streams (wild only) and estimated numbers of emigrating wild coho fry during 1991-1992.

Table 6. Total number of cutthroat trout caught in fry traps and estimated total emigration during 1991-1993.

	Actual catch			Estimated migrants		
Stream	1991	1992	1993	1991	1992	1993
Bull	217	146	155	244	270	211
Prairie	115	307	133	122	334	141
Peterson	127	97	104	127	126	119
0042	143	120	30	152	136	40
Elkhorn	104	187	115	104	210	126
Hunt	185	193	113	199	241	179

Actual catch and estimated numbers of emigrating wild and hatchery coho smolts varied between streams (Table 7). Variability in the numbers of wild coho smolts emigrating from study streams was relatively small between years, with the exception of Peterson and 0042 Creeks. These two streams produced many more wild coho smolts during 1992 than during either 1991 or 1993. Estimates of wild smolt emigration ranged from 0 in Prairie Creek (1991 and 1993) to 558 in Bull Creek (1993). The number of hatchery coho smolts emigrating from streams the year following supplementation was much lower than that of wild coho smolts emigrating, with the exception of Hunt Creek during 1992. Hatchery coho fry stocked during 1991 smolted from 1991 control streams located downstream, evidently as a result of winter redistributions. Daily emigration patterns of wild and hatchery coho smolts are listed in Figures C.7-C.12 in Appendix C.

Actual catch and estimated emigration of steelhead showed moderate variability between streams and years when compared to other emigrating salmonids (Table 8). Estimated emigration ranged from 4 to 207 steelhead. Emigration of zero age trout was much greater during 1991 than 1992 and 1993, when no zero age trout were caught (Table 9). Nearly all zero age trout caught during this study were from 0042 Creek. Daily emigration patterns of steelhead and zero age trout are displayed graphically in Figures C.12-C.14 in Appendix C.

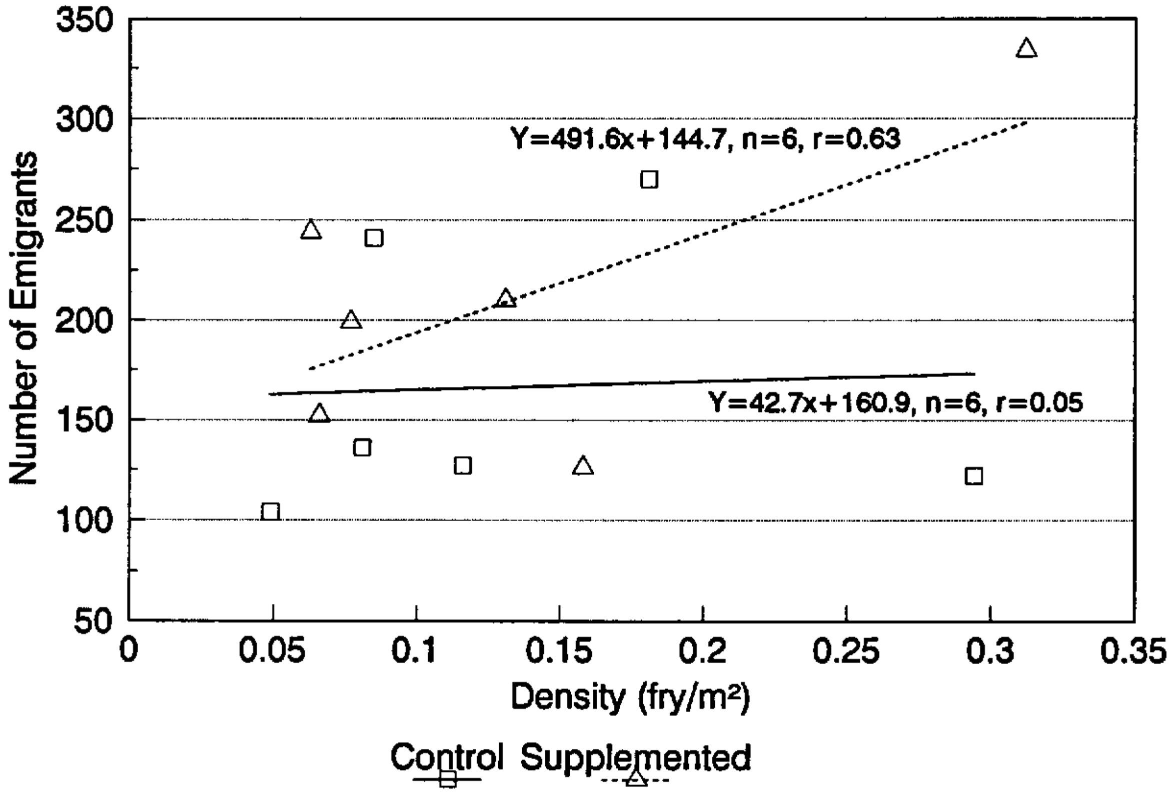

Figure 3. **Relationship between observed densities (fish/m² pool area) of cutthroat trout in supplemented and control streams during June (Peters 1996) and estimated numbers of cutthroat trout emigrating from these streams during 1991-1992.**

Table 7. Total number of wild coho smolts caught in fry traps and estimates of total emigration during 1991-1993.

	Actual Catch					Estimated Migrants				
Stream	1991[a]	1992		1993		1991[a]	1992		1993	
		Wild	Hatchery	Wild	Hatchery	Wild	Wild	Hatchery	Wild	Hatchery
Bull	432	287	15	458	0	501	378	20	558	0
Prairie	0	6	0	0	5	0	6	0	0	5
Peterson	23	510	2	68	20	23	610	2	79	21
0042	24	162	34	22	0	26	168	36	21	0
Elkhorn	244	386	6	74	5	244	411	6	91	5
Hunt	307	430	265	311	0	335	464	285	338	0

[a]Only wild coho smolts were present during 1991

Table 8. Total number of steelhead trout caught in fry traps and estimates of total emigration during 1991-1993.

	Actual catch			Estimated migrants		
Stream	1991	1992	1993	1991	1992	1993
Bull	193	25	122	205	41	136
Prairie	18	35	24	19	37	25
Peterson	207	125	53	207	126	55
0042	19	30	4	20	33	4
Elkhorn	75	85	16	75	88	16
Hunt	62	69	22	66	74	22

Table 9. Total number of zero age trout caught in fry traps and estimates of total emigration during 1991-1993.

	Total Catch			Estimated Migrants		
Stream	1991	1992	1993	1991	1992	1993
Bull	0	0	0	0	0	0
Prairie	9	0	0	11	0	0
Peterson	0	0	0	0	0	0
0042	49	0	0	50	0	0
Elkhorn	0	0	0	1	0	0
Hunt	1	0	0	1	0	0

Effect of Coho Fry Supplementation on Salmonid Emigration Rates

Contradictory results were obtained regarding the influence of coho salmon fry supplementation on the emigration rate of wild coho fry (Figure 4). Wild coho fry in supplemented streams emigrated earlier than those in control streams during 1991 (Figure 4). In contrast, overall emigration of wild coho salmon occurred earlier in control streams than in supplemented streams during 1992, although initial emigration was earlier in supplemented streams (Figure 4). When data from both years were combined, the results indicated that wild coho fry in supplemented streams emigrated earlier than those in control streams.

The emigration rate of cutthroat trout generally was unaffected by coho salmon fry supplementation (Figure 5). Cutthroat trout emigration in control streams was significantly later than in supplemented streams during 1992. However, no significant differences in cutthroat trout emigration rates were observed during 1991, or when data from 1991 and 1992 were combined. Emigration rates of wild coho smolts were unaffected by coho fry supplementation (Figure 6). No significant differences in wild coho smolt emigration rates were detected between control and supplemented streams during 1991 and 1992. Nor were differences detected when data from the two years were combined.

Emigration rates of steelhead trout appeared to be increased by coho salmon fry supplementation (Figure 7), although the results were inconsistent. No significant difference was observed in the emigration rates of steelhead in supplemented and control streams during 1991. However, steelhead trout in supplemented streams emigrated significantly faster than those in control streams during 1992. This difference was maintained when data from 1991 and 1992 were combined (Figure 8).

Wild and hatchery coho salmon fry and smolts each displayed significantly different rates of emigration from supplemented streams (Figure 8-9). Hatchery coho fry emigrated from supplemented streams much faster than wild coho fry during both 1991 and 1992 (Figure 8). This difference was maintained when data from 1991 and 1992 were combined. In contrast, hatchery coho smolts emigrated from supplemented streams significantly slower than wild coho smolts (Figure 9). This difference existed during both 1991 and 1992 as well as when data from both years were combined.

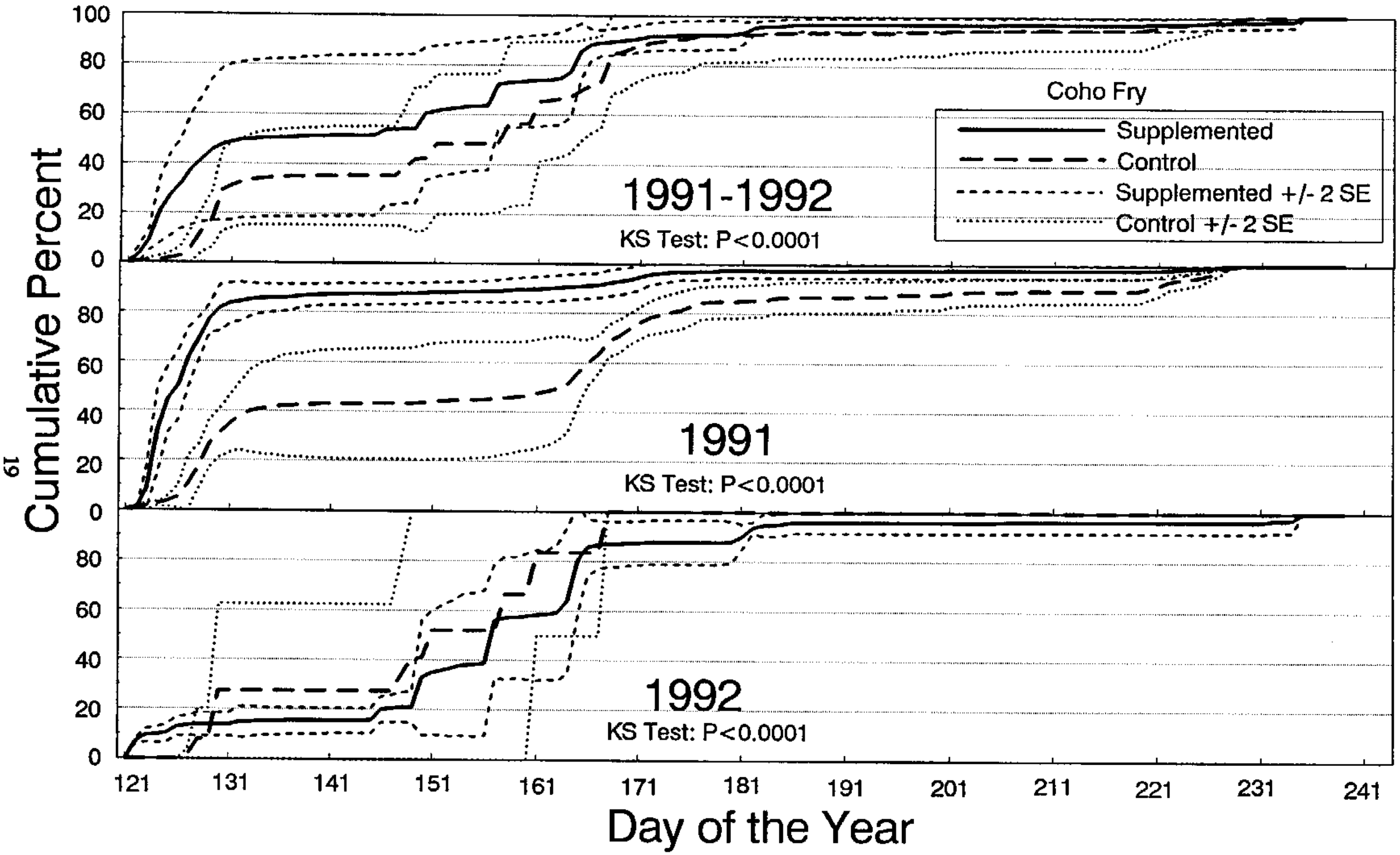

Figure 4. **Cumulative percent emigration of wild coho salmon fry from supplemented and control streams during 1991-1992. Fine dashed and dotted lines represent the range (+/- 2 SE) for control and supplemented streams, respectively.**

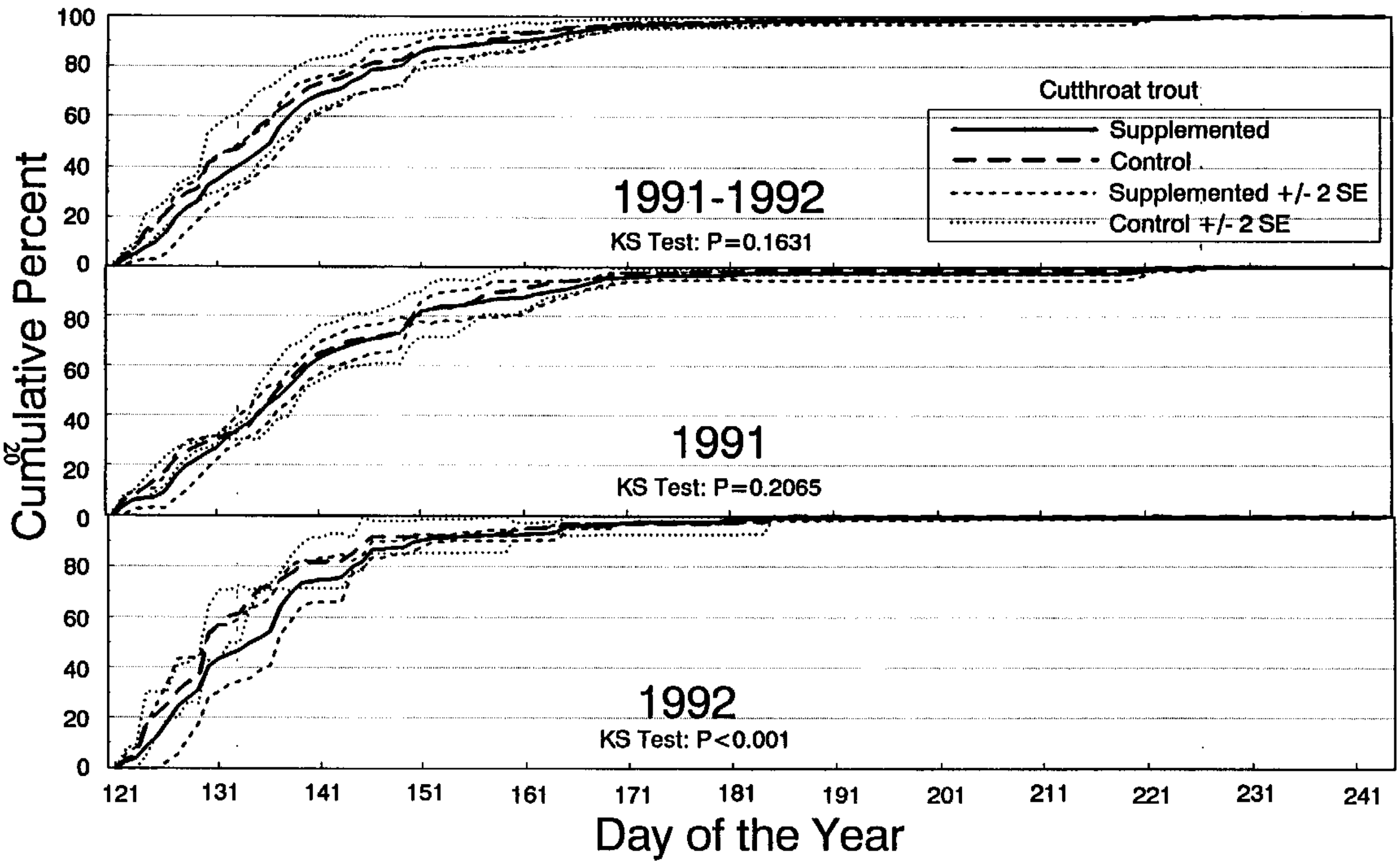

Figure 5. Cumulative percent emigration of cutthroat trout from supplemented and control streams during 1991-1992. Fine dashed and dotted lines represent the range (+/- 2 SE) for control and supplemented streams, respectively.

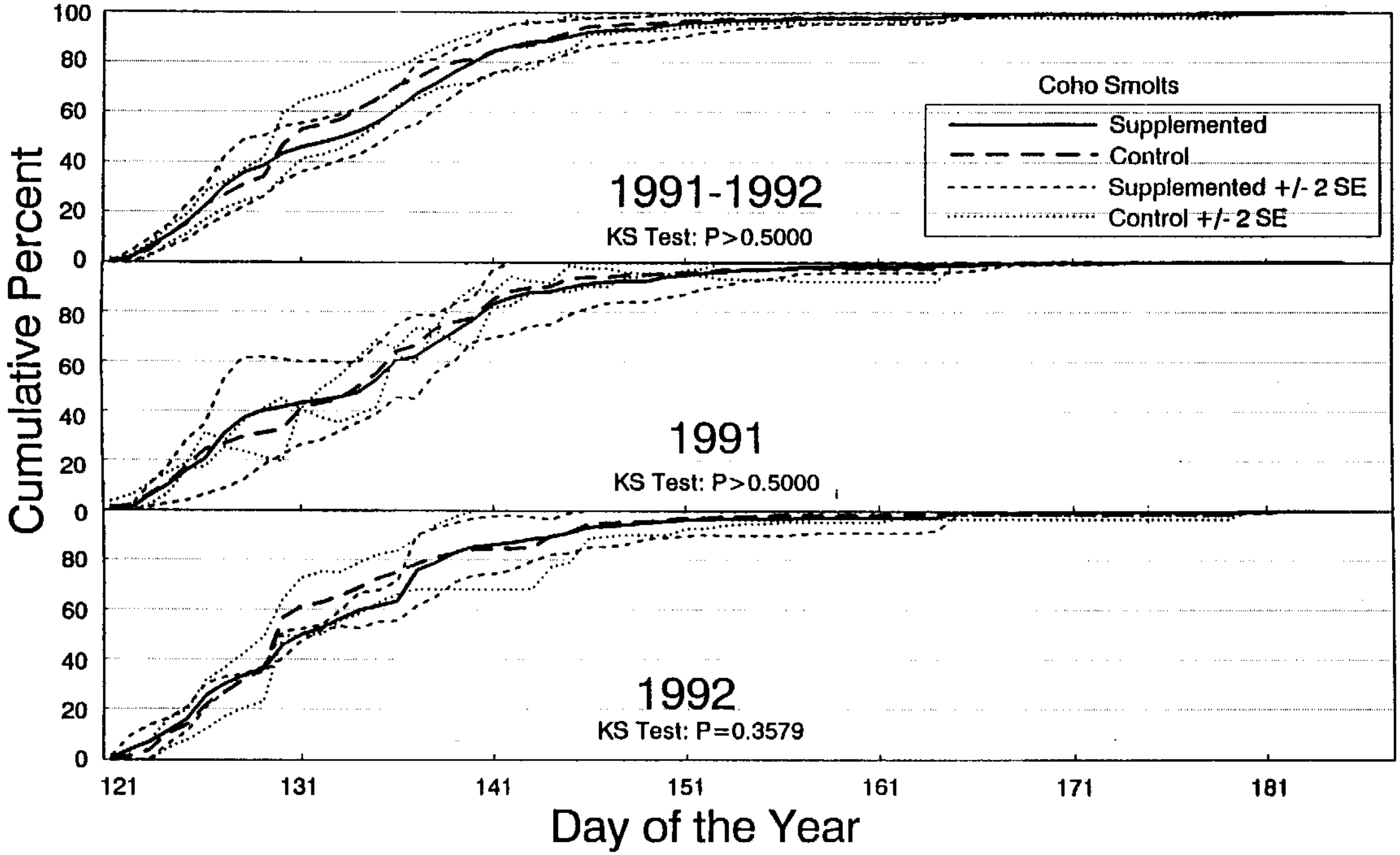

Figure 6. Cumulative percent emigration of wild coho smolts from supplemented and control streams during 1991-1992. Fine dashed and dotted lines represent the range (+/- 2 SE) for control and supplemented streams, respectively.

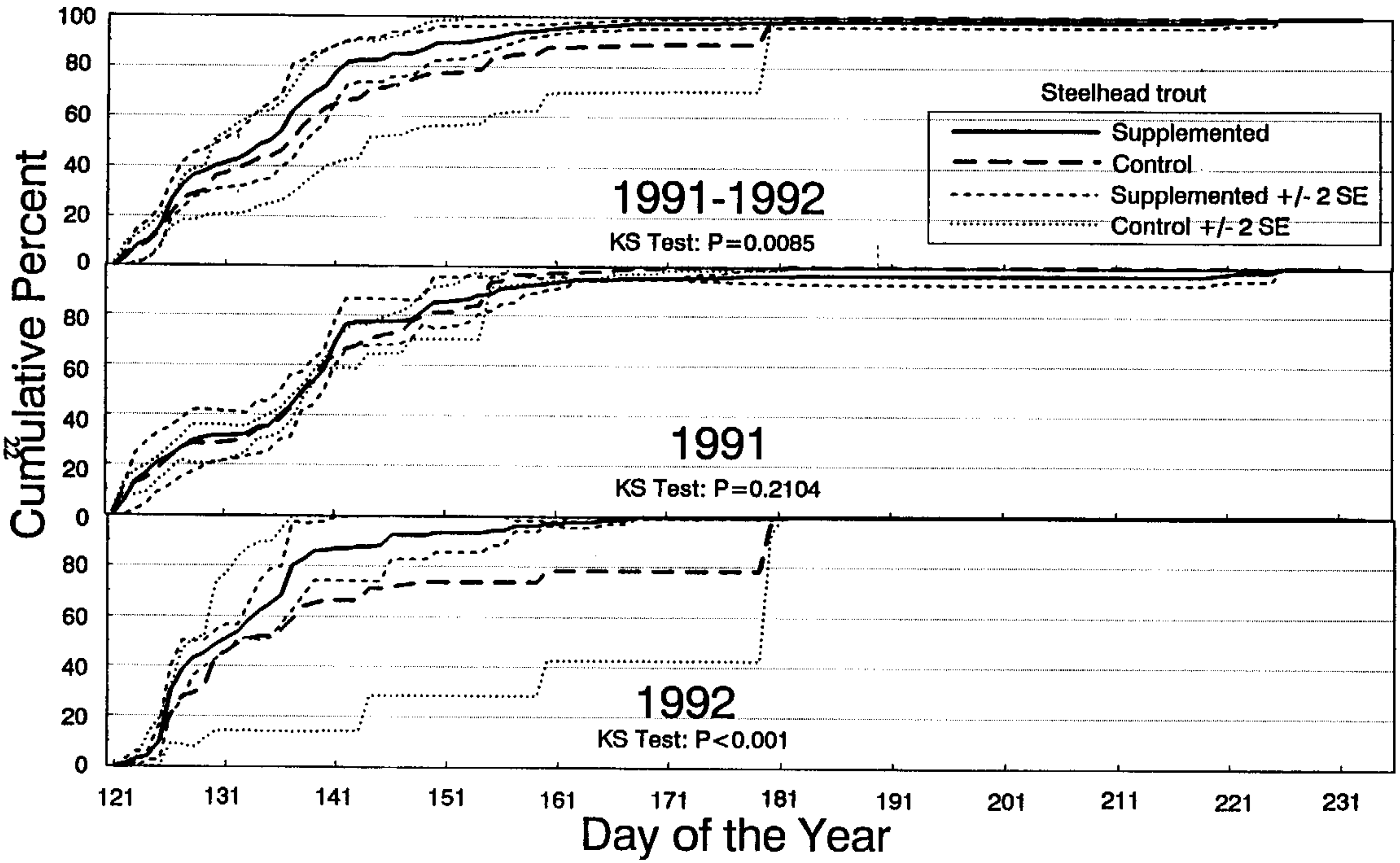

Figure 7. Cumulative percent emigration of steelhead from supplemented and control streams during 1991-1992. Fine dashed and dotted lines represent the range (+/- 2 SE) for control and supplemented streams, respectively.

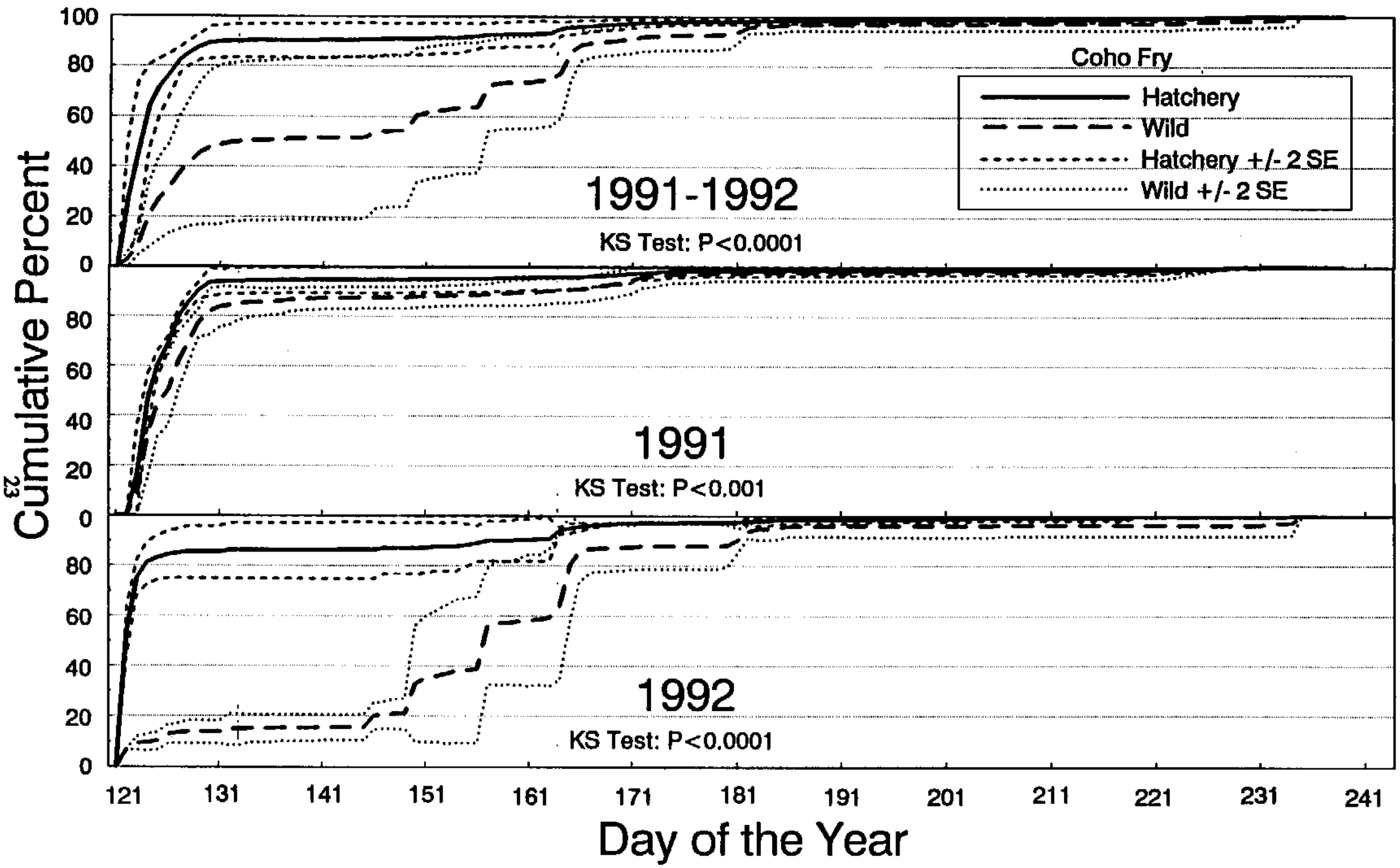

Figure 8. Cumulative percent emigration of wild and hatchery coho salmon fry from supplemented streams during 1991-1992. Fine dashed and dotted lines represent the range (+/- 2 SE) for hatchery and wild fish, respectively.

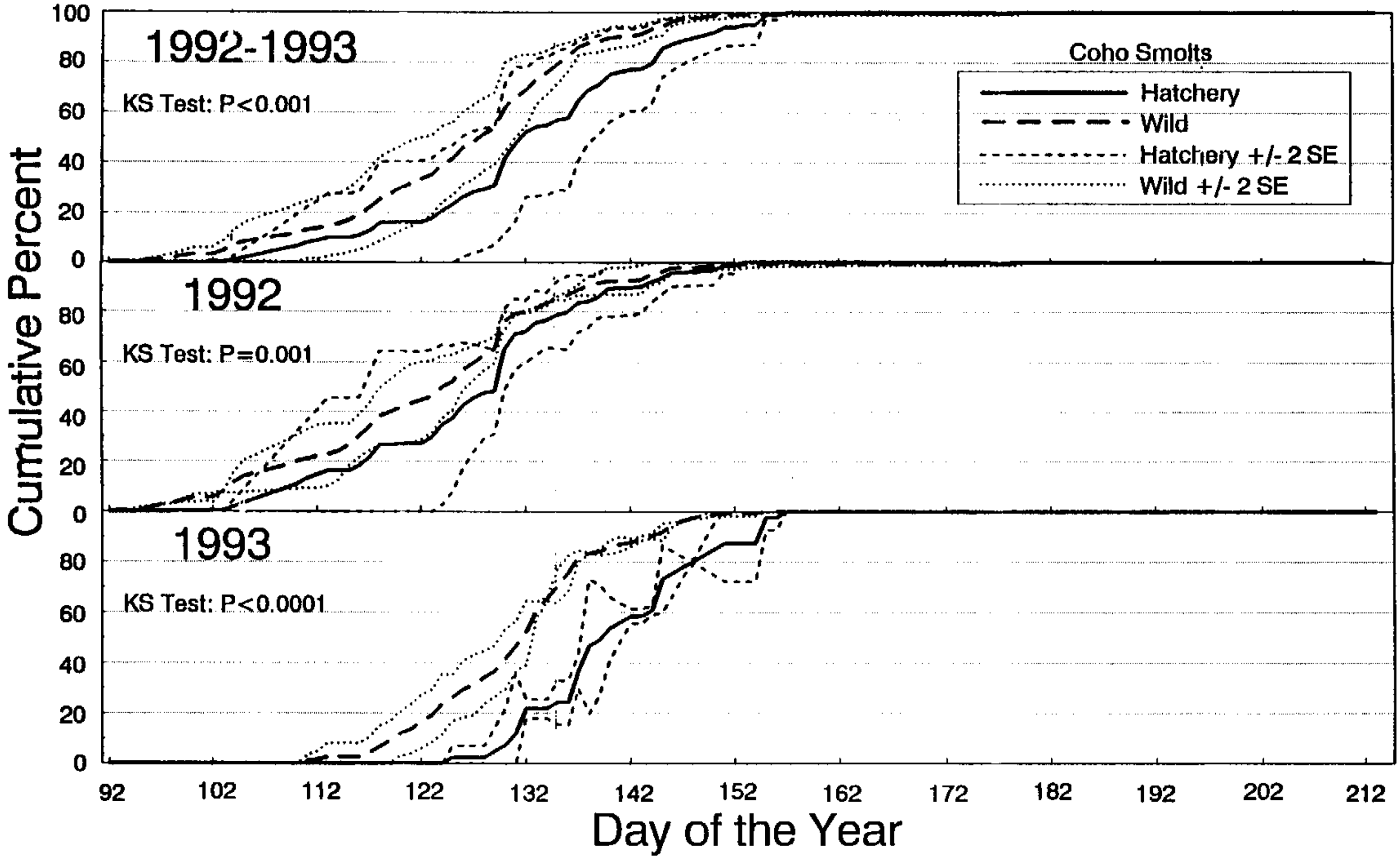

Figure 9. Cumulative percent emigration of wild and hatchery coho salmon smolts from supplemented streams during 1992-1993. Fine dashed and dotted lines represent the range (+/- 2 SE) for hatchery and wild fish, respectively.

Effects of Coho Fry Supplementation on Lengths of Emigrating Salmonids

No consistent difference in the length of wild coho fry emigrating from supplemented and control streams was observed before or after stocking hatchery-reared coho fry (Figure 10). Wild coho salmon fry emigrating prior to stocking hatchery-reared coho salmon fry were larger than those migrating after stocking in 0042 Creek during 1991 (t-test: $P=0.0001$). However, wild coho salmon fry emigrating prior to stocking were smaller than those migrating after stocking in Hunt Creek during 1991 (t-test: $P=0.0001$). No difference was observed in Bull Creek (1991) (t-test: $P=0.6571$) or Elkhorn Creek (1992) (t-test: $P=0.4074$). No test was possible for either Prairie Creek or Peterson Creek because too few fish emigrated before and after stocking.

Average length of wild coho fry emigrating from supplemented streams appeared to be negatively influenced by coho fry supplementation during 1991. Wild coho salmon emigrating from supplemented streams were smaller than those emigrating from control streams (ANCOVA: $P=0.0001$). The size of emigrating wild coho salmon in control streams increased during the trapping period at a greater (ANCOVA: $P=0.001$) rate (slope) than in supplemented streams (Figure 10). Insufficient numbers of emigrating wild coho fry were observed in supplemented and control streams during 1992 for meaningful statistical comparisons.

Emigrating hatchery coho salmon fry were generally larger than wild coho fry in supplemented streams during 1991, however the opposite was true during 1992 (Figures 2.10-14). Hatchery coho fry emigrating from 0042 (ANCOVA: $P=0.0046$) and Hunt Creek (ANCOVA: $P=0.0001$) were larger than wild coho salmon fry during 1991 (Figures 11-12). No difference (ANCOVA: $P=0.3008$) was detected between the fork lengths of wild and hatchery coho fry emigrating from Bull Creek during 1991 (Figure 13). The change in the fork length of emigrating wild and hatchery coho salmon fry during the trapping season was not different in 0042 (ANCOVA: $P=0.4523$) or Bull Creek (ANCOVA: $P=0.2103$) during 1991. However, lengths of emigrating wild coho fry increased more (ANCOVA: $P=0.0001$) during the trapping season than that of hatchery coho salmon in Hunt Creek (Figure 14).

No difference was detected in the lengths of wild and hatchery coho fry emigrating from Elkhorn Creek during 1992 (ANCOVA: $P=0.7866$). In contrast, wild coho salmon in Peterson Creek were larger than emigrating hatchery fry during 1992 (ANOVA: $P=0.0001$). The length of wild and hatchery coho salmon emigrating from Elkhorn Creek during 1992 did not change differently (ANCOVA: $P=0.7981$) during the trapping season (Figure 15). However, the lengths of emigrating wild coho salmon in Peterson Creek increased more (ANCOVA: $P=0.0001$) during trapping than the lengths of hatchery coho fry (Figure 16). Insufficient data existed for meaningful comparisons in Prairie Creek.

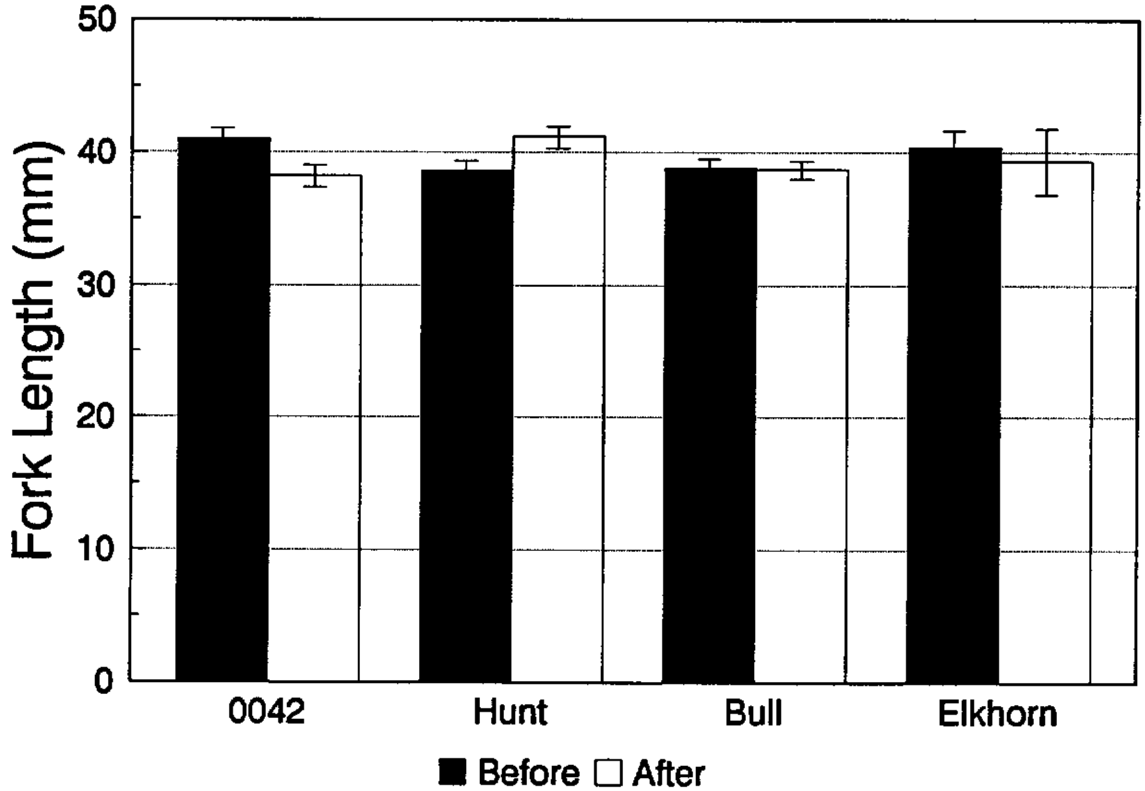

Figure 10. Mean fork length (+/- 2 SE) of wild coho salmon fry emigrating from supplemented streams the day before and the day after stocking with hatchery-reared coho salmon fry during 1991 (0042, Hunt, Bull) and 1992 (Elkhorn).

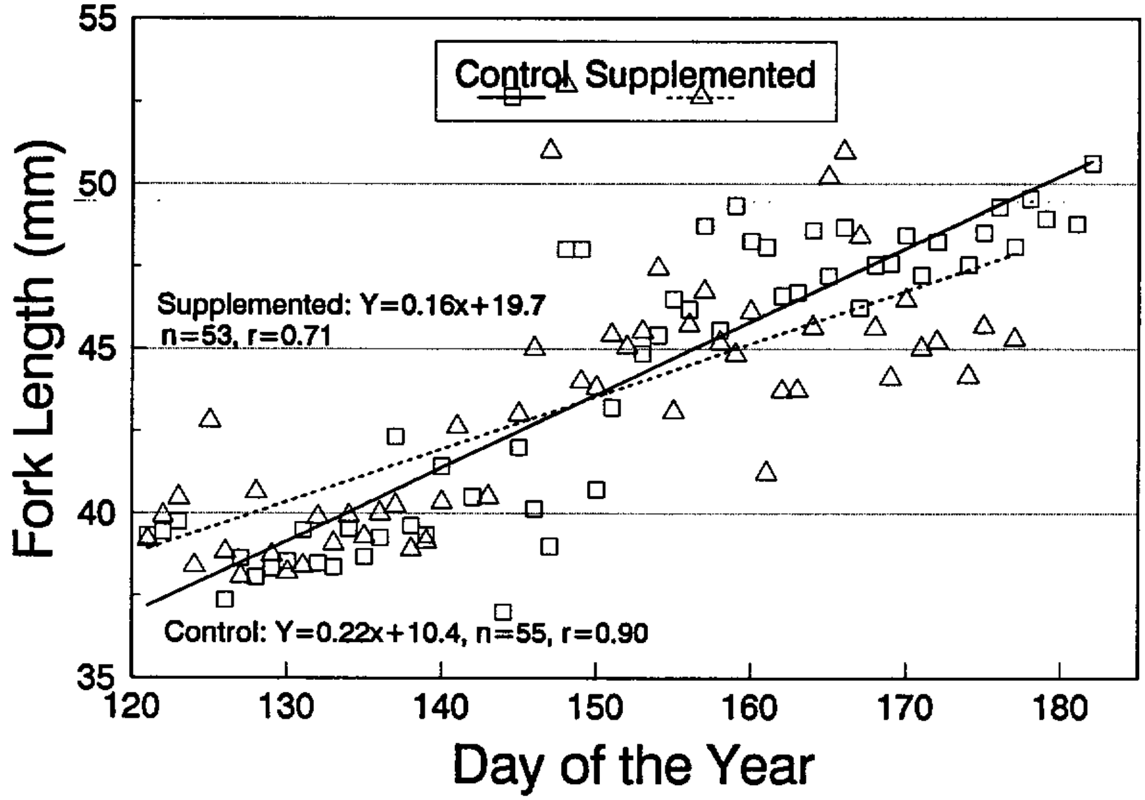

Figure 11. Changes in fork length of wild coho fry emigrating from supplemented and control streams during 1991. Data included date from when hatchery coho fry were stocked to the last day when both wild and hatchery coho fry were caught emigrating from the stream.

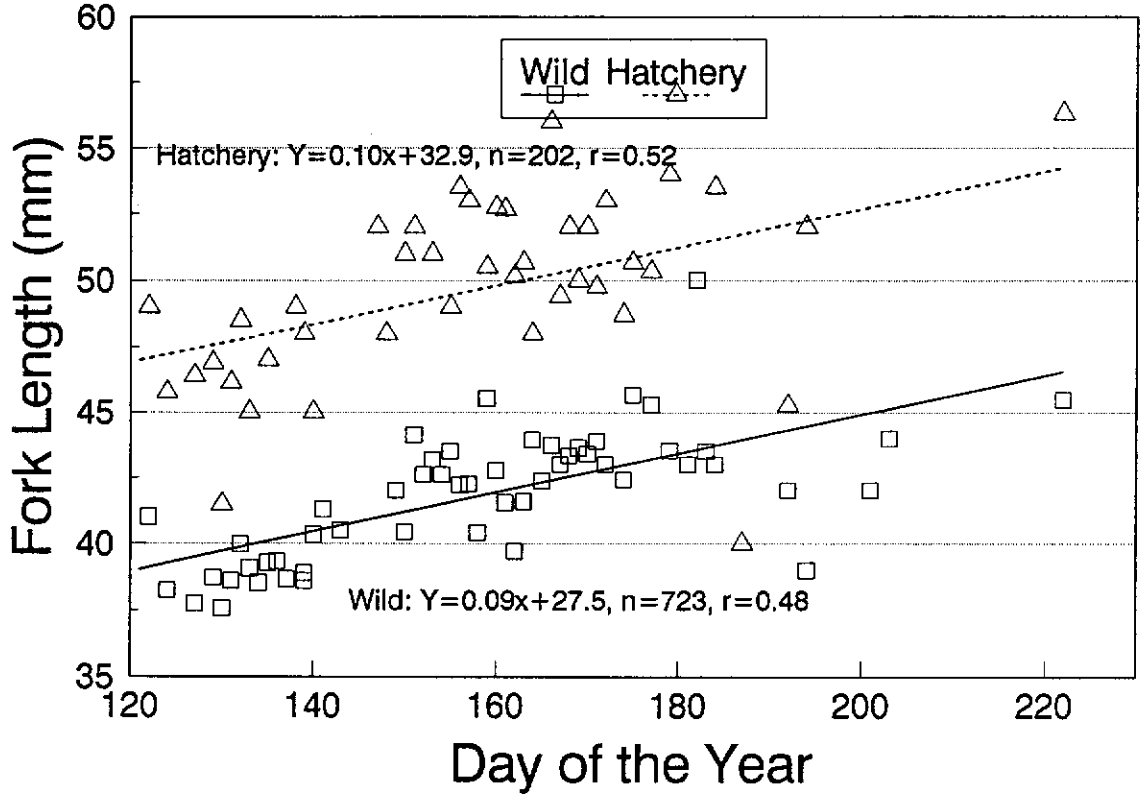

Figure 12. Changes in mean fork lengths of wild and hatchery-reared coho fry emigrating from 0042 Creek during 1991. Data includes dates from when hatchery coho fry were stocked to the last day when both wild and hatchery coho fry were caught emigrating from the stream.

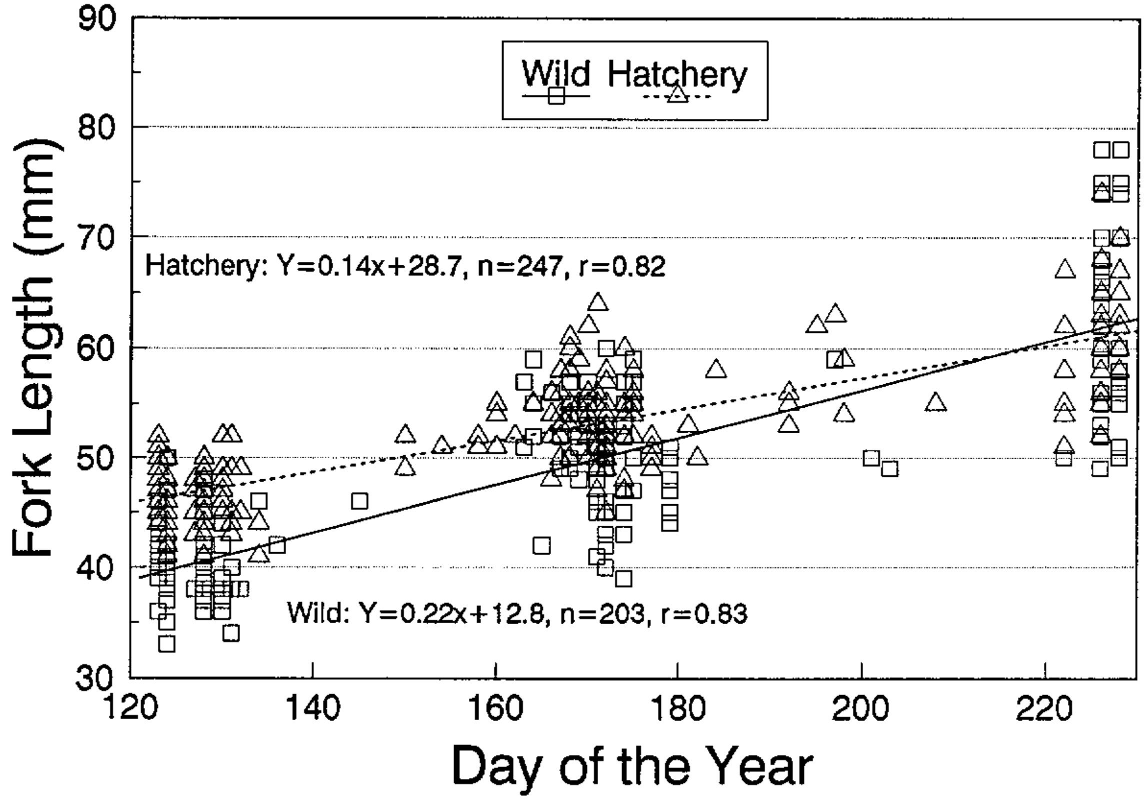

Figure 13. **Changes in mean fork lengths of wild and hatchery-reared coho fry emigrating from Hunt Creek during 1991. Data includes dates from when hatchery coho fry were stocked to the last day when both wild and hatchery coho fry were caught emigrating from the stream.**

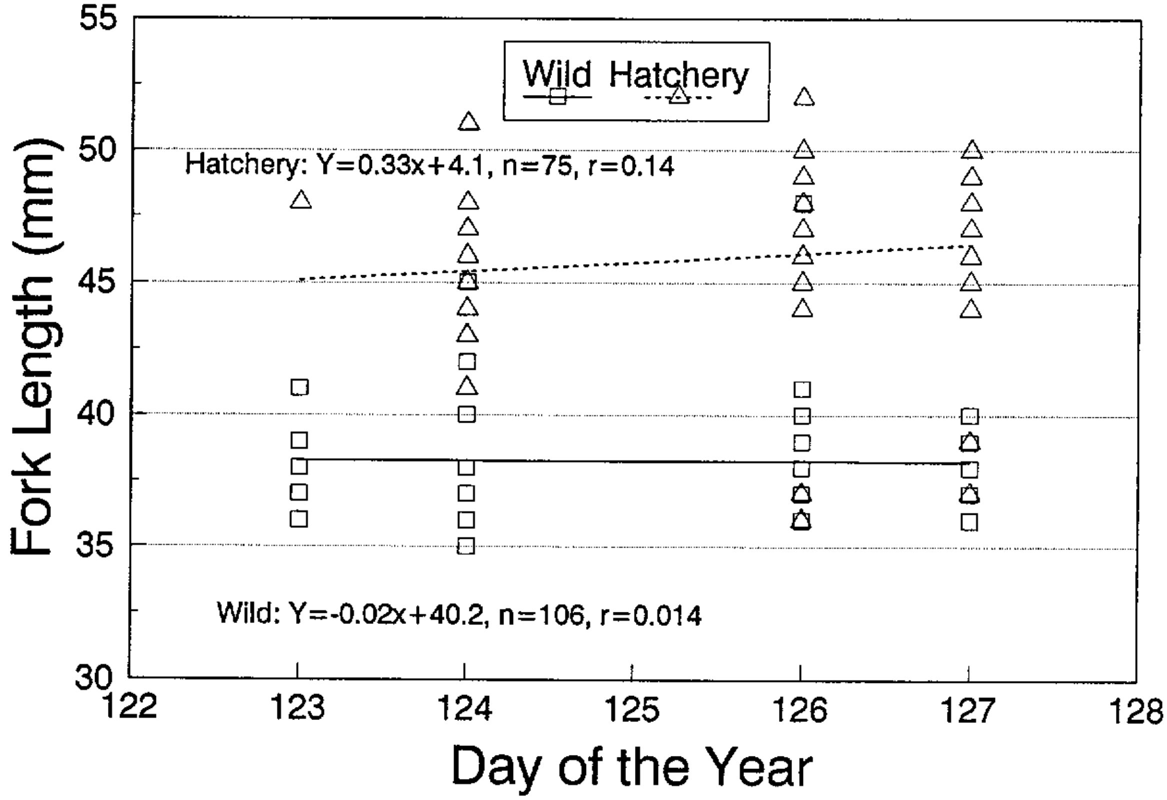

Figure 14. **Changes in mean fork lengths of wild and hatchery-reared coho fry emigrating from Bull Creek during 1991. Data includes dates from when hatchery coho fry were stocked to the last day when both wild and hatchery coho fry were caught emigrating from the stream.**

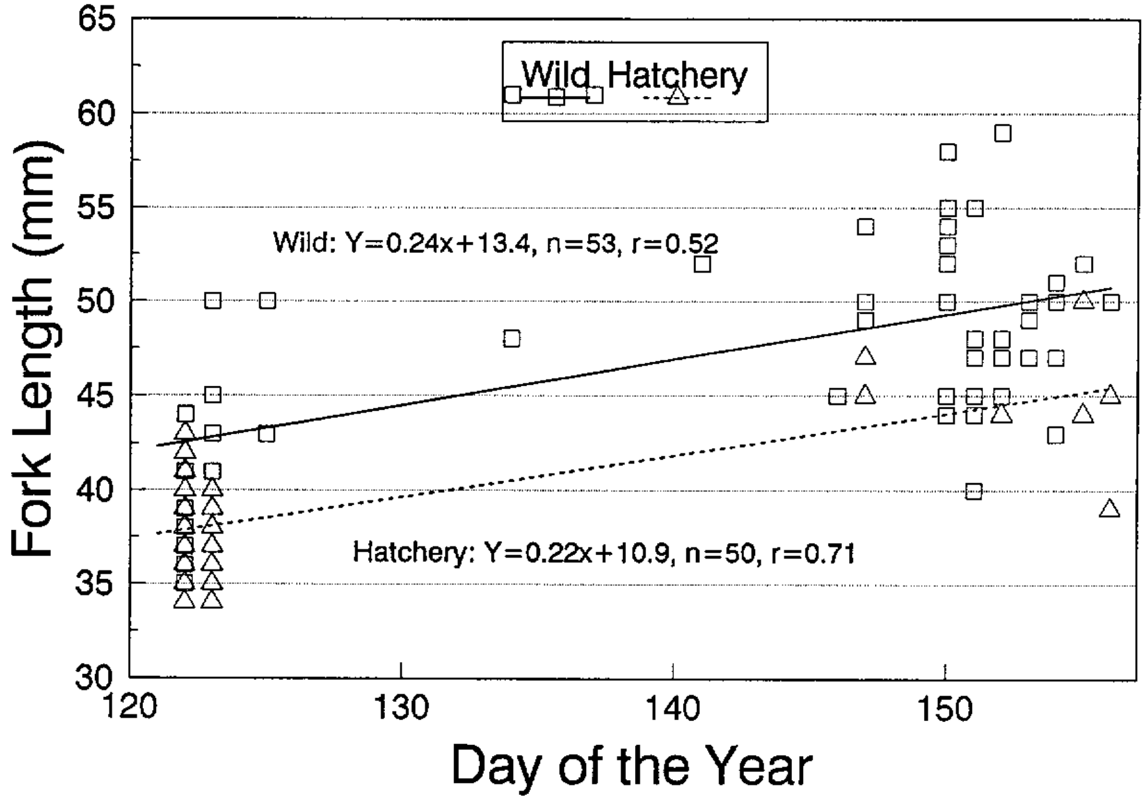

Figure 15. **Changes in mean fork lengths of wild and hatchery-reared coho fry emigrating from Elkhorn Creek during 1992. Data includes dates from when hatchery coho fry were stocked to the last day when both wild and hatchery coho fry were caught emigrating from the stream.**

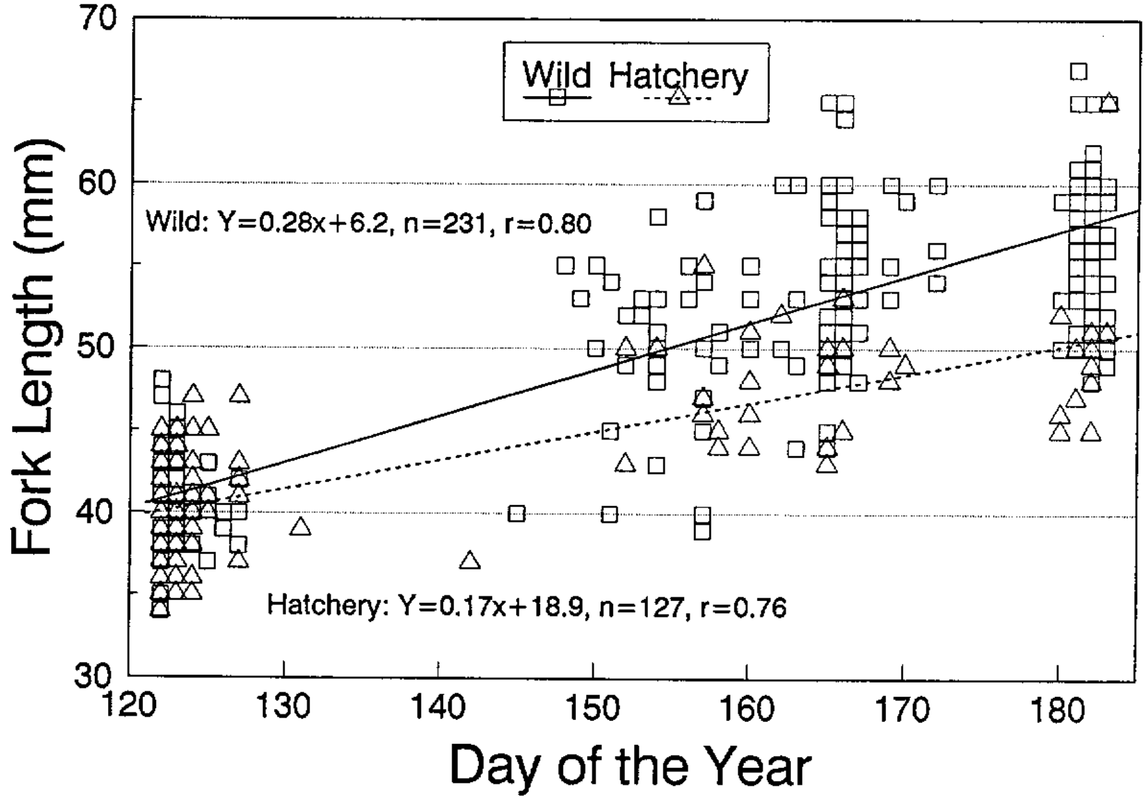

Figure 16. **Changes in mean fork lengths of wild and hatchery-reared coho fry emigrating from Peterson Creek during 1992. Data includes dates from when hatchery coho fry were stocked to the last day both wild and hatchery coho fry were caught emigrating from the stream.**

Significant differences in the fork length of wild coho salmon smolts existed between years and treatments (control vs. supplemented). Wild coho smolts were larger in 1993 (Mean = 103.2, SD = 8.98) than in 1992 (Mean = 98.3, SD = 9.30) (two-way ANOVA: P=0.0001) and in supplemented streams (Mean = 100.4, SD = 10.27) than in control streams (Mean = 99.8, SD = 10.86) (two-way ANOVA: P=0.0001). No interaction was detected between the factors treatment and year (two-way ANOVA: P=0.9894).

No consistent trend existed between wild and hatchery-reared coho smolt lengths in supplemented streams (Figure 17). Wild and hatchery coho smolt lengths were not different in 0042 Creek (t-test: 1992: P=0.1384, Power < 0.30), Bull Creek (t-test: 1992: P=0.5448; Power <0.30); or Elkhorn Creek (t-test: P=0.1558; Power < 0.30); however, the power of these tests was low. Hatchery coho smolts were larger than wild coho salmon smolts in Hunt Creek during 1992 (t-test: P=0.0001). In contrast, wild coho salmon smolts were larger than hatchery coho smolts in Peterson Creek during 1993 (t-test: P=0.0001). No comparison was possible for Prairie Creek due to too few emigrants.

Fate of Emigrating Coho Salmon

Emigrating wild and hatchery-reared coho salmon fry freeze branded and released below fry traps took up residency in habitats downstream of the traps. From limited electroshocking observations it appears that wild coho salmon fry emigrating past our traps may have been more likely to reside in downstream habitats than hatchery-reared coho salmon fry (Table 10). The recovery rate of branded wild fry below the Bull Creek trap was 3.25% compared to 0.66% for hatchery-reared coho salmon. However, a large number (136) of unbranded hatchery-reared coho fry were observed below this trap. Unbranded hatchery-reared coho salmon either migrated while the trap was not fishing or the brands faded. An estimated 426 wild and 810 hatchery-reared coho salmon fry emigrated past the trap without being branded during brief periods while the trap was not fishing from the beginning of trapping and the 29 July 1991 survey. The recovery rate of hatchery-reared coho salmon fry below the trap, based on the total number of hatchery-reared coho salmon fry (branded and unbranded) recovered, was 3.28% which is similar to the recovery rate of wild coho fry. However, it is likely that some of the unbranded wild coho salmon observed below the trap had also migrated while the trap was not fishing. This would result in an increased recovery rate for wild fish as well. Recoveries of both wild and hatchery-reared coho salmon fry were less in Shale Creek than Bull Creek.

Wild and hatchery coho salmon in the mainstem Clearwater River were sampled with beach and purse seines from 16 July through 29 July and examined for brands. Juvenile coho salmon from 52 debris accumulations in the mainstem Clearwater River were sampled and examined for brands

(Table 11). Branded wild and/or hatchery-reared coho fry or unbranded hatchery coho fry were recovered at 22 of the 52 stations during the July sampling. Wild coho salmon branded in Bull, Peterson, 0042, and Elkhorn creeks were recovered (Table 12). Recoveries of branded hatchery coho salmon were all from Bull Creek. Wild coho salmon had migrated from 0 to 10 km downstream once they entered the mainstem (Figure 18). However, two marked fish from Elkhorn Creek had moved upstream approximately 300 m from the mouth of Elkhorn Creek. Both marked hatchery-reared coho salmon originated from Bull Creek and had moved downstream (0-2 km).

A second survey of the mainstem Clearwater River was completed from 9 September to 16 September (Table 11). Eleven mainstem debris accumulations were sampled during this survey, with branded wild coho fry or unbranded hatchery-reared coho fry being recovered at six of these accumulations (Figure 18). However only two branded wild coho fry and no hatchery-reared coho fry were recovered during this survey. Marked wild coho salmon originated from Bull Creek and Peterson Creek and had traveled 10 km and 4 km, respectively.

Immigrant fry traps were operated on six wall-base channel outlet streams from 5 September 1991 to 7 January 1992. During this period 7,008 wild and 151 hatchery-reared juvenile coho salmon were caught immigrating into wall-base channels. Seven wild coho fry had been branded at the tributary fry traps, while none of the hatchery-reared coho fry had been branded (Table 12). One of the fry originating from 0042 Creek had migrated upstream approximately 2.4 km, while the other two had migrated 2.4 km downstream. The one marked wild coho salmon from Elkhorn Creek had migrated upstream approximately 300 m from this tributary to immigrate into Paradise Pond (Figure 18). All other migrations were downstream (Peterson Creek: 16 km; Prairie Creek: 22.5 km; Hunt Creek: 7.5 km).

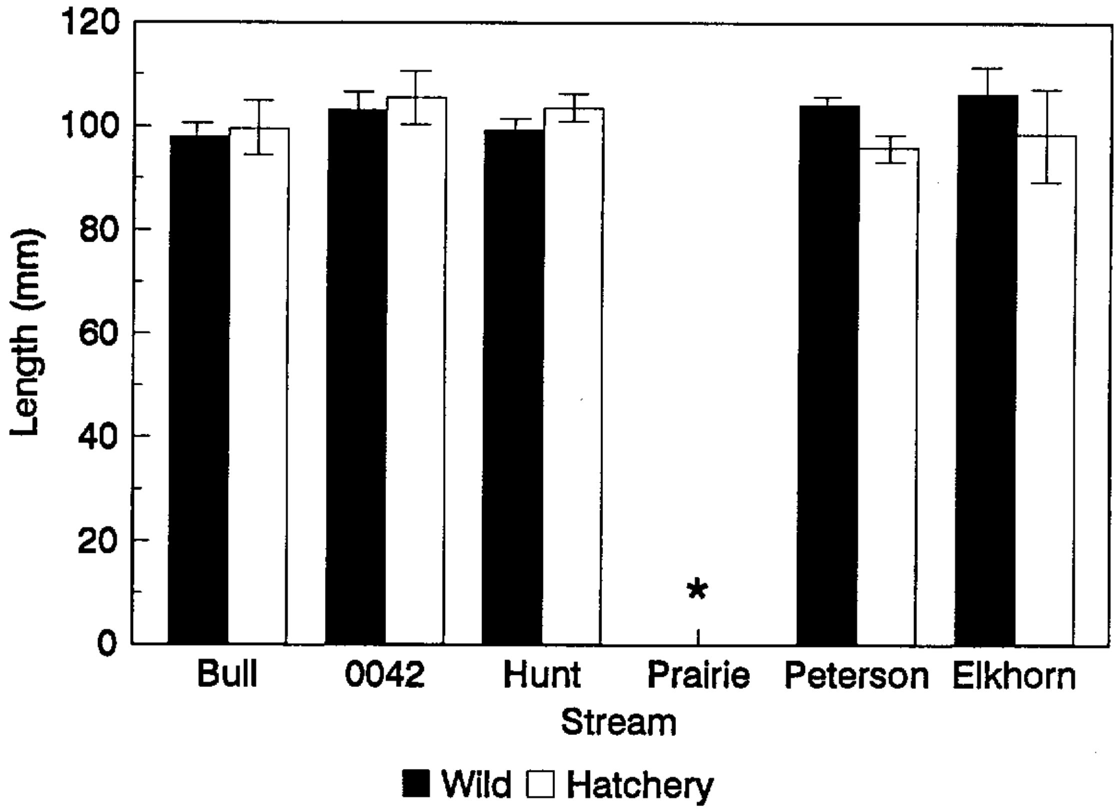

Figure 17. Mean fork length of wild and hatchery coho smolts emigrating from 0042, Bull, Hunt, Peterson, and Elkhorn creeks the year following supplementation. (* indicates no comparison possible in Prairie Creek.

Table 10. Number of wild and hatchery-reared coho salmon fry (marked and unmarked) captured during electrofishing surveys below tributary traps during 1991.

Stream	Date	Wild Coho Fry				Hatchery-Reared Coho Fry					
		Marked	Total	Number Branded	Percent Recovered	Marked	Total	Number Branded	Percent Recovered	Estimated Migration	Percent Recovered[b]
Peterson	26 June	80	367	2,952	2.71%						
Elkhorn	2 July	65	135	2,442	2.66%						
Bull	29 July	32	402	984	3.25%	13	149	1,975	0.66%	4547	3.28%
Shale	30-31 July	28	403	2,713[a]	1.03%	1	1	1,090	0.09%	1578	0.06%
Peterson	21 August	58	385	3,098	1.87%						
Elkhorn	26 August	47	134	2,614	1.80%						

[a]Branded in 0042 Creek, which is a tributary to Shale Creek.
[b]Number of Hatchery fish + number of hatchery fish branded.

Table 11. The number of wild and hatchery-reared coho fry examined for brands and the number having brands in the mainstem Clearwater River (July and September 1991) and wall-base channels (September 1991 and January 1992).

Recovery Location	Date	Wild		Hatchery	
		Number Examined	Number with Brands	Number Examined	Number with Brands
Mainstem	16 July - 30 July	3,606	36	64	2
Mainstem	9 Sept. - 16 Sept.	603	2	12	0
Wall-base Channels	5 Sept. 1991 - 7 January 1992	7,008	7	151	0

Table 12. Number and location (Noted in Figure 20) (number at that location) of wild and hatchery-reared coho salmon from each tributary recovered in the mainstem Clearwater River and six wall-base channels. Recoveries of hatchery coho salmon include branded fish and unbranded fish which were sacrificed for CWT recovery.

Origin	Number Recovered	Location (#)	Number Recovered	Location (#)
		Mainstem Recoveries (16 July - 30 July 1991)		
Bull	6	a(1); f(1); h(1)	9	a(3); c(3); g(1); k(1); n(1)
Prairie	0		0	
Peterson	11	i(5); j(2); k(1); m(2); n(1)	0	
0042	1	o	0	
Elkhorn	17	p(3); q(5); r(1); s(4); t(4)	0	
Hunt	0		1	v
		Mainstem Recoveries (9 September - 16 September 1991)		
Bull	1	D	0	
Prairie	0		0	
Peterson	1	D	0	
0042	0		0	
Elkhorn	0		0	
Hunt	0		0	
		Wall-Base Channel Recoveries (5 September 1991 - 7 January 1992)		
Bull	0			
Prairie	1	6	0	
Peterson	1	5	0	
0042	3	2(1); 3(1); 4(1)	0	
Elkhorn	1	3	0	
Hunt	1	6	0	

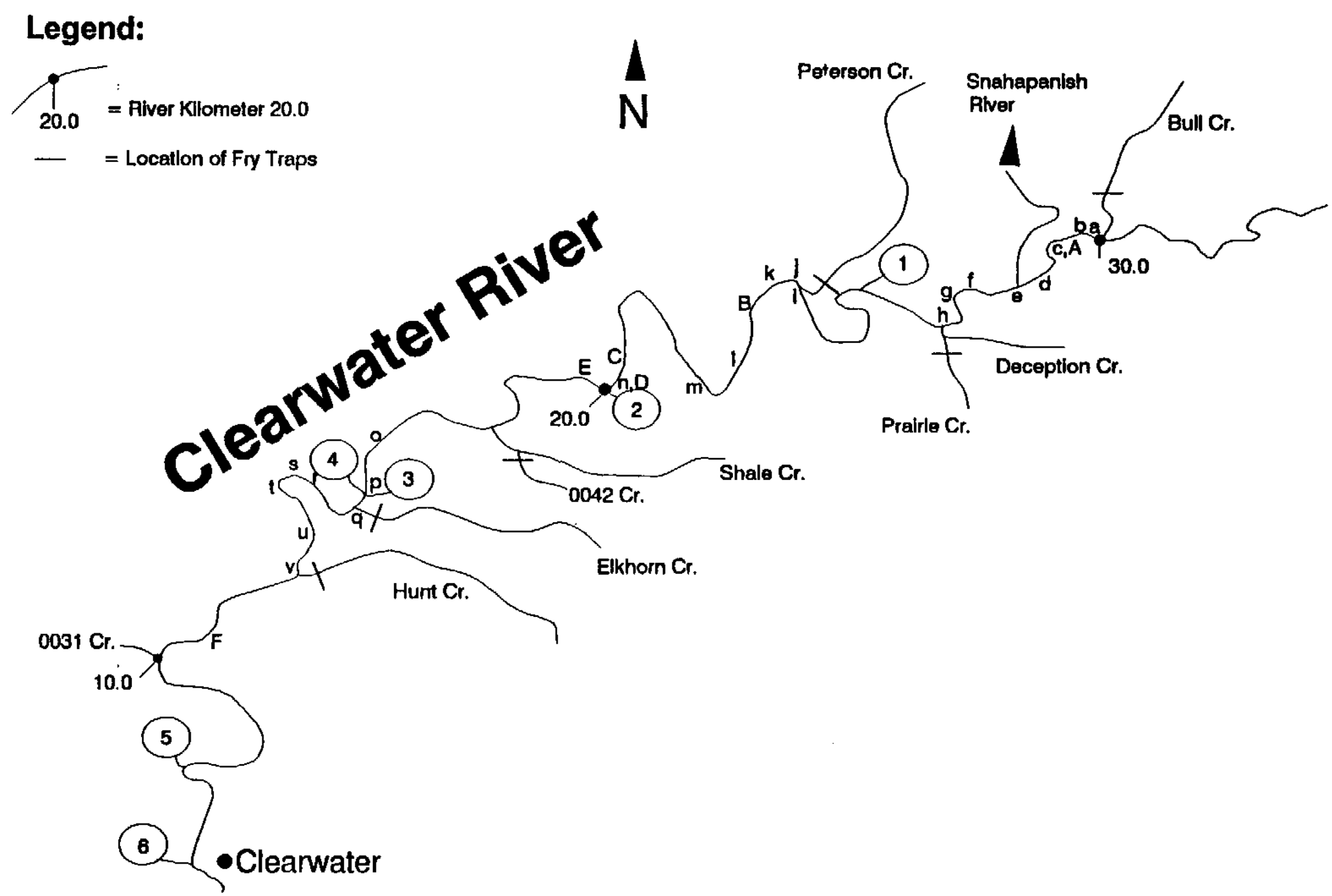

Figure 18. Location where coho salmon fry marked at tributary traps were recovered in the mainstem and wall-base channels during 1991. Letters correspond to those listed in Table 12.

DISCUSSION

Total emigration of wild coho fry and cutthroat trout was not increased by stocking tributaries of the Clearwater River with hatchery-reared coho fry obtained from a native broodstock. However, the relationship between total emigration of wild coho fry and cutthroat trout and June rearing densities of these species were different in supplemented and control streams. Wild coho fry emigrated earlier in supplemented streams than those in control streams. The emigration timing of cutthroat trout appeared to be delayed by coho fry supplementation. Total emigration of hatchery-reared coho fry varied between 9.3% and 46.9%. Hatchery-reared coho salmon emigrated earlier than wild coho salmon and were less likely to take up residency than wild coho fry in habitats downstream of emigration traps. The magnitude and rate of hatchery-reared coho fry emigration and potential increases in wild coho fry emigration could reduce the ability of supplementation programs to successfully increase total coho salmon densities in streams.

This study failed to demonstrate that supplementing small streams with hatchery-reared coho salmon produced from a native broodstock increased total numbers of wild coho fry and cutthroat trout emigrating from streams. However, there was evidence that the wild coho fry and cutthroat trout emigration was disrupted by coho fry supplementation. A strong relationship existed between the estimated number of wild coho fry emigrating from control streams and rearing densities observed during June. Total estimated emigration of wild coho fry was low when June rearing densities were low and high when June rearing densities were high. In contrast, there was little relationship between the number of cutthroat trout emigrating from the streams and early summer rearing densities in control streams. However, cutthroat trout emigration increased as rearing densities increased in supplemented streams.

Competition for food and space regulates coho salmon populations in small streams (Chapman 1966) apparently by causing increased emigration of 'surplus' fish (Chapman 1962). Thus, the observation of increased wild coho fry emigration with increased early summer rearing densities is the expected result. The disruption of this relationship in control streams is an indication that coho fry supplementation negatively impacted wild coho fry in these streams. Although differences were not statistically different, visual examination of the differences in these relationships suggests significant biological implications. However, the early summer wild coho fry rearing densities did not appear to be reduced by coho fry supplementation (Chapter III). The disruption of cutthroat trout emigration was not as clear as that for wild coho fry. This may have been due to differences in intra- and interspecific competition between wild coho fry and cutthroat trout, with stocked hatchery-reared coho fry. Although the relationship between cutthroat emigration and early summer rearing densities was disrupted this did not result in reduced early summer rearing densities of cutthroat trout (Chapter III).

Competition for food and space should be greatest for species exhibiting the greatest degree of spatial and niche overlap. Although hatchery-rearing may alter habitat selection (Dickson and MacCrimmon 1982), hatchery-reared coho salmon would be expected to occupied habitats similar to that of wild coho salmon and cutthroat trout underyearling (Glova 1987). Most of the cutthroat trout emigrating from the study streams we sampled appeared to be yearlings based on size. It seems unlikely that yearling cutthroat trout and stocked hatchery-reared coho fry would compete for the same habitat. It seems more likely that hatchery-reared coho fry would be preyed upon by yearling cutthroat trout. Therefore, competition may have influenced emigration of wild coho salmon, while food abundance may have influenced emigration of cutthroat trout. Published literature supports the hypothesis that native salmonids expected to occupy microhabitats similar to that of the stocked salmonids are generally more likely to be negatively impacted by stocking than those occupying less similar habitats. However, some conflicting evidence also is available.

Stocking hatchery-reared salmonids generally has not increased emigration of native salmonids which occupy different microhabitats than stocked salmonids. Stocked age 0+ Atlantic salmon selected different habitat than wild age 0+ wild rainbow trout and did not affect the timing of movement (Hearn and Kynard 1986). Stocking hatchery-reared coho salmon in side-channels of the Wenatchee River, Washington, resulted in a habitat shift by chinook salmon, but did increase emigration of chinook salmon or steelhead (Spaulding et al. 1989). Hatchery "thinning" releases of age zero steelhead did not result in increased emigration of wild chinook salmon (Hillman and Mullan 1989). In contrast, "thinning" releases of chinook salmon resulted in increased emigration of steelhead trout. However, competition between chinook and steelhead was not apparent. Wild steelhead appeared to be "pulled" downstream by emigrating hatchery chinook salmon (Hillman and Mullan 1989).

Stocking hatchery-reared salmonids has generally increased the emigration of native salmonids expected to occupy microhabitats similar to those of stocked fish. Hatchery-reared coho salmon, originating from both hatchery and native stocks, affected microhabitat use and foraging behavior, and caused a greater rate of downstream movement in wild coho salmon (Nielsen 1994). This increased emigration reduced production in two of four wild coho salmon foraging phenotypes, but did not significantly reduce overall production in the study streams (Nielsen 1994). Hatchery "thinning" releases of chinook salmon increased emigration of wild chinook salmon (Hillman and Mullan 1989). However, this appeared to be the result of wild chinook being "pulled" by emigrating hatchery chinook rather than competition between the two groups. In contrast, hatchery "thinning" releases of steelhead (age 0) did not increase emigration of wild steelhead (Hillman and Mullan 1989). However, this evaluation lasted only 24 hours. Hatchery steelhead dispersed very little during this time, originally moving to the bottom where they displayed little activity. This behavior would increase densities in localized areas, but may not have increase competition within the 24 hour evaluation period. Potential impacts may have occurred following the 24-hour evaluation period, when hatchery steelhead began displaying more natural behavior.

This study did not provide conclusive evidence that the emigration rates of wild coho salmon and other native salmonids were significantly altered by coho fry supplementation. Although several studies have examined the influence of stocking hatchery-reared salmonids on total emigration or habitat shifts in native salmonids, I could find no published information discussing the impacts of stocking on the emigration rates of native salmonids.

The effect of coho fry supplementation on the emigration rates of wild coho salmon may have been density dependent, size related, or related to the physical nature of the study streams. Emigration rates of wild coho salmon were increased during 1991 when the greatest densities were observed. However, hatchery-reared coho fry also were larger than wild coho fry during 1991, which would be expected to provide hatchery-reared coho fry a competitive advantage. Emigration of wild coho fry occurred earlier in Bull, Hunt, and 0042 creeks whether they were supplemented or not. However, emigration rates were much earlier during 1991, when they were supplemented, than in 1992, when they were not. Emigration of wild coho fry initially occurred earlier in supplemented streams (Elkhorn, Prairie, Peterson) during 1992 even though hatchery-reared coho fry were smaller during this year. However, overall wild coho fry emigration occurred earlier in control streams (Bull, Hunt, 0042) during 1992. Thus, it appears that the differences in emigration timing in the different study streams may have masked the effect of stocking hatchery-reared coho fry on wild coho fry emigration.

Coho fry supplementation did not appear to significantly increase the emigration rate of cutthroat trout. When emigration timing was influenced it was delayed. It's possible that cutthroat trout remained in supplemented streams to feed on hatchery-reared coho salmon. However, if coho fry were such an important food source to alter cutthroat trout emigration behavior, one would expect the delayed emigration to have occurred during 1991, when coho salmon densities were greatest, rather than 1992.

Coho fry supplementation increased the emigration rate of steelhead during one year but not the other. The effect of densities as a causative mechanism increasing the emigration rates of steelhead trout could not be assessed with available data. Emigration rates of steelhead were slower during 1991 when coho salmon densities were greatest. However, steelhead densities were not measured and could have influenced emigration rates of steelhead trout.

Poor survival of hatchery-reared salmonids following stocking is thought to be a major factor leading to the failure of many supplementation programs (Sosiak et al. 1979; Dickson and MacCrimmon 1982; Irvine and Baily 1992). Data from this study suggest that emigration of hatchery-reared coho salmon may be a significant factor resulting in apparent mortality of stocked hatchery-reared coho fry. In two of six cases, over 40% of stocked hatchery-reared coho salmon emigrated from the stream into which they were planted. Hatchery coho fry stocked in streams lacking native coho salmon populations also showed significant total emigration (37-69%) (Bilby and Bisson 1987). Hatchery-reared coho salmon also emigrated much earlier than wild coho fry and were less likely to take up residency in habitats downstream of emigration traps following their release. Emigration patterns of hatchery coho fry observed in the present study were similar to those of hatchery coho fry stocked into streams lacking native coho salmon populations (Bilby and Bisson 1987). The early emigration of hatchery-reared juvenile coho salmon could result in reduced survival by exposing these fish to high flow conditions in the mainstem. This is supported by the few emigrants observed in habitats downstream of the emigration traps. Since emigrating wild and hatchery-reared coho salmon were not differentially marked over time, it is impossible to determine if differences in likelihood to take up residency in downstream habitat were related to emigration timing.

This study did not provide conclusive evidence regarding the impacts of coho fry supplementation on the emigration rate and magnitude of wild coho salmon. However, potential negative impacts of coho fry supplementation on wild coho salmon emigration, and for increased emigration of stocked hatchery-reared coho salmon, appeared to be density related. Stocking densities used in the present study (3 fry/m^2 pool) may be too high for effective supplementation of natural coho salmon stocks. Additional evaluation of the effects of supplementation on native coho salmon populations should be completed using much lower stocking densities. This would reduce competition between wild and hatchery-reared coho salmon, which may reduce impacts to total emigration and emigration rates of both wild and hatchery-reared coho salmon. The early emigration timing could be a significant factor contributing to past failures of coho fry supplementation programs.

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LITERATURE CITED

Bachman, R.A. 1984. Foraging behavior of free-ranging wild and hatchery brown trout in a stream. Transactions of the American Fisheries Society 113:1-32.

Bilby, R.E., and P.A. Bisson. 1987. Emigration and production of hatchery coho salmon (*Oncorhynchus kisutch*) stocked in streams draining an old-growth and a clear-cut watershed. Canadian Journal of Fisheries and Aquatic Sciences 44:1397-1407.

Bisson, P.A., K. Sullivan, and J.L. Nielson. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead and cutthroat trout in streams. Transactions of the American Fisheries Society 117:262-273.

Bryant, M.D., and W.J. Walkotten. 1980. Carbon dioxide freeze-branding device for use on juvenile salmonids. Progressive Fish-Culturist 42:55-56.

Buchanan, D.V., J.E. Sanders, J.L. Zinn, and J.L. Fryer. 1983. Relative susceptibility of four strains of summer steelhead to infection by *Ceratromyxa shasta*. Transactions of the American Fisheries Society 112:541-543.

Cederholm, C.J., and W.J. Scarlett. 1982. Seasonal immigration of juvenile salmonids into four small tributaries of the Clearwater River, Washington, 1977-1981. Pages 98-110 *in* E.L. Brannon and E.O. Salo, editors. Salmon and trout migratory behavior symposium, University of Washington, Seattle, Washington.

Chandler, G.L., and T.C. Bjornn. 1988. Abundance, growth, and interactions of juvenile steelhead relative to time of emergence. Transactions of the American Fisheries Society 117:432-443.

Chapman, D.W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. Journal of the Fisheries Research Board of Canada. 19:1047-1080.

Chapman, D.W. 1966. Food and space as regulators of salmonid populations in streams. The American Naturalist 100:345-357.

Chilcote, M., S. Leider, and J. Lock 1986. Differential reproductive success of hatchery and wild summer steelhead under natural conditions. Transactions of the American Fisheries Society 115:726-735.

Dickson, T.A., and H.R. MacCrimmon. 1982. Influence of hatchery experience on growth and behavior of juvenile Atlantic salmon (*Salmo salar*) within allopatric and sympatric stream populations. Canadian Journal of Fisheries and Aquatic Sciences 39:1453-1458.

Fenderson, O.C., W.H. Everhart, and K.M. Muth. 1968. Comparative agonistic and feeding behavior of hatchery-reared and wild salmon in aquaria. Journal of the Fisheries Research Board of Canada 25:1-14.

Fenderson, O.C., and M.R. Carpenter. 1971. Effects of crowding on the behavior of juvenile hatchery and wild landlocked atlantic salmon (*Salmo salar* L.). Animal Behaviour 19:439-447.

Foster, J.R. 1977. Pulsed gastric lavage - an efficient method of removing the stomach contents of live fish. The Progressive Fish-Culturist 39:166-169.

Fraser, F.J., E.A. Perry, and D.T. Lightly. 1983. Big Qualicum River salmon development project. Volume 1. Biological Assessment 1959-1972. Canadian Technical Report in Fisheries and Aquatic Sciences 1189: 198 pp.

Godfrey, H. 1965. Coho salmon in offshore waters, Pages 1-39, *in* Salmon of the North Pacific Ocean. Part IX. Coho, chinook, and masu salmon in offshore waters. International North Pacific Fisheries Commission Bulletin 16.

Glova, G.J. 1987. Comparison of allopatric cutthroat trout stocks with those sympatric with coho salmon and sculpins in small streams. Environmental Biology of Fishes 20(4):275-284.

Hearn, W.E., and B.E. Kynard. 1986. Habitat utilization and behavioral interaction of juvenile Atlantic salmon (*Salmo salar*) and rainbow trout (*S. gairdneri*) in tributaries of the White River of Vermont. Canadian Journal of Fisheries and Aquatic Sciences 43:1988-1998.

Heggens, J. 1988. Effects of short-term flow fluctuations on displacement of, and habitat use by, brown trout in a small stream. Transactions of the American Fisheries Society 117:336-344.

Helle, J.H. 1984. "Gene Banks" for wild fish stocks. *in*, J.M. Dalton, and D.B. Houston, editors. Proceedings of the Olympic Wild Fish Conference. Fishery Technician Program, Peninsula College, Port Angeles, Washington.

Hemmingsen, A.R., R.A. Holt, and R.E. Ewing. 1986. Susceptibility of progeny from crosses among three stocks of coho salmon to infection by *Ceratromyxa shasta*. Transactions of the American Fisheries Society 115:492-495.

Hesthagen, T. 1988. Movements of brown trout, *Salmo trutta*, and juvenile Atlantic salmon, *Salmo salar*, in a coastal stream in norther Norway. Journal of Fish Biology 32:639-653.

Hillman, T.W., and D.W. Chapman. 1989b. Abundance, habitat use, and overlap of wild steelhead juveniles and stocked rainbow trout, pages 109-155, in Don Chapman Consultants, inc., editor, Summer and Winter Ecology of Juvenile Chinook Salmon and Steelhead trout in the Wenatchee River, Washington, Final Report submitted to Chelan County Public Utility District, Washington.

Hillman, T.W., and J.W. Mullan. 1989. Effect of hatchery releases on the abundance and behavior of wild juvenile salmonids. pages 265-285, in Don Chapman Consultants, inc., editor, Summer and Winter Ecology of Juvenile Chinook Salmon and Steelhead trout in the Wenatchee River, Washington, Final Report submitted to Chelan County Public Utility District, Washington.

Hurst, R. 1993. Coho colonization - a semi-natural method for coho enhancement. Pages 1151-158, *in* L. Berg and P.W. Delaney, editors. Proceedings of the coho workshop, Nanaimo, B.C., May 26-28, 1992.

Irvine, J.R. 1986. Effects of varying discharge on the downstream movement of salmon fry, *Oncorhynchus tshawytscha*. Journal of Fish Biology 28:17-28.

Irvine, J.R. and R.E. Bailey. 1992. Some effects of stocking coho salmon fry and supplemental instream feeding of wild and hatchery-origin salmon. North American Journal of Fisheries Management 12:125-130.

Jenkins, T.M., Jr. 1969. Social structure, position choice and microdistribution of two trout species (*Salmo trutta* and *S. gairdneri*) resident in mountain streams. Animal Behaviour Monograph 2:57-123.

Leider, S.A., P.L. Hulett, J.J. Loch, and M.W. Chilcote. 1990. Electrophoretic comparison of the reproductive success of naturally spawning transplanted and wild steelhead trout through the returning adult stage. Aquaculture 88:239-252.

Lestelle, L.C., G.R. Blair, and S.A. Chitwood. 1993. Approaches to supplementing coho salmon in the Queets River, Washington. Pages 104-119, *in* L. Berg and P.W. Delaney, editors. Proceedings of the coho workshop, Nanaimo, B.C., May 26-28, 1992.

Mason, J.C. 1966. Behavioral ecology of juvenile coho salmon (O. kisutch) in stream aquaria with particular reference to competition and aggressive behavior. Ph.D. Dissertation. Oregon State University, Corvallis, Oregon 195 p.

Mason, J.C., and D.W. Chapman. 1965. Significance of early emergence, environmental rearing capacity, and behavioral ecology of juvenile coho salmon in streams and channels. Journal of the Fisheries Research Board of Canada. 22:173-190.

McMahon, T.E., and G.F. Hartman. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 46:1551-1557.

Miller, R.B. 1954. Comparative survival of wild and hatchery-reared cutthroat trout in a stream. Transactions of the American Fisheries Society. 83:120-130.

Moring, J.R., and D.V. Buchanan. 1979. Downstream movements and catches of two strains of stocked trout. Journal of Wildlife Management 42:329-333.

Nehlsen, W., J.E. Williams, and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4-21.

Nickelson, T., M. Solazzi, and S. Johnson. 1986. Use of hatchery coho salmon presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences. 43:2443-2449.

Nielsen, J.L. 1994. Invasive cohorts: impacts of hatchery-reared coho salmon on the trophic development, and genetic ecology of wild stocks. Pages 361-385, *in* D.J. Strouder, K.L. Fresh, R.J. Feller, editors, M. Duke, assistant editor. Theory and Application in fish feeding ecology, Proceedings of GUTSHOP '92 held in November 1992, at Rosario Resort, San Juan Islands, Washington.

Petrosky, C.E., and T.C. Bjornn. 1988. Response of wild rainbow trout (*Salmo gairdneri*) and cutthroat trout (*S. clarki*) to stocked rainbow trout in fertile and infertile streams. Canadian Journal of Fisheries and Aquatic Sciences 45:2087-2105.

Pollard, H.A. II., T.C. Bjornn. 1973. The effects of angling and hatchery trout on the abundance of juvenile steelhead trout. Transactions of the American Fisheries Society 102:745-752.

Quinault Indian Nation. 1992. Evaluation of wild coho supplementation in the Queets river. Final Report to: The Northwest Indian Fisheries Commission. Prepared by Quinault Department of Natural Resources, Fisheries Division, Contract No. 3109 FY-91

Quinault Indian Nation. 1993. Evaluation of wild coho supplementation in the Queets river. Final Report to: The Northwest Indian Fisheries Commission. Prepared by Quinault Department of Natural Resources, Fisheries Division, Contract No. 3109 FY-92

Reisenbichler, R.R., and J.D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 34:123-128.

Sosiak, A.J., R.G. Randall, and J.A. McKenzie. 1979. Feeding by hatchery-reared and wild Atlantic salmon (*Salmo salar*) parr in streams. Journal of the Fisheries Research Board of Canada 36:1408-1412.

Spaulding, J.S., T.W. Hillman, and J.S. Griffith. 1989. Habitat use, growth, and movement of chinook salmon and steelhead in response to introduced coho salmon. Pages 156-208, *in* Don Chapman Consultants, Inc., editor, Summer and winter ecology of juvenile chinook salmon and steelhead trout in the Wenatchee River, Washington. Final Report to Chelan County Public Utility District, Washington.

Steward, C.R. nd T.C. Bjornn. 1990. Supplementation of salmon and steelhead stocks with hatchery fish: a synthesis of published literature. University of Idaho, Idaho Cooperative Fish and Wildlife Research Unit, Technical Report 90-1, Moscow, Idaho.

Swain, D.P., and B.E. Ridell. 1990. Variation in agonistic behavior between newly emerged juveniles from hatchery and wild populations of coho salmon, *Oncorhynchus kisutch*. Canadian Journal of Fisheries and Aquatic Sciences 47:566-571.

Symons, P.E.K. 1969. Greater dispersal of wild compared with hatchery-reared juvenile Atlantic salmon released in streams. Journal of the Fisheries Research Board of Canada 26:1867-1876.

Tripp, D., and P. McCarty 1983. Effects of different coho stocking strategies on coho and cutthroat trout production in isolated headwater streams. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1212

Vincent, E.R. 1987. Effects of stocking catchable-size hatchery rainbow trout on two wild trout species in the Madison River and O'Dell Creek, Montana. North American Journal of Fisheries Management 7:91-105.

Wampler, P., J. Anderson, and E. Knudsen. 1990. Evaluation of planting native hatchery coho fry into streams containing wild coho fry. Western Washington Fishery Resource Office, U.S. Fish and Wildlife Service, Olympia, Washington.

Winter, B.D., and P.L. Wampler. 1990. Steelhead trout habitat analysis using the instream flow incremental methodology for six tributaries of the Clearwater River, Washington. U.S. Fish and Wildlife Service, Fisheries Assistance Office, Olympia, Washington.

Wunderlich, R., and C. Pantaleo. 1995. A review of methods to re-introduce anadromous fish in the Elwha River. Western Washington Fishery Resource Office, U.S. Fish and Wildlife Service, Olympia, WA.

Zar, J.H. 1984. Biostatistical analysis, second edition. Prentice-Hall, Englewood Cliffs, New Jersey.

APPENDIX A: Operation dates of fry traps in study streams during 1991-1993.

Table A.1. Dates of operation for spring fry traps in 6 streams within the Clearwater River system during 1991-1993.

Stream	Trap Installed	Trap Removed	Dates not Fishing
1991			
Bull	4/27	8/5	5/8-10, 5/30
Hunt	4/24	8/21	5/8-9, 5/13, 7/7, 8/6-9
0042	4/27	8/21	5/8, 8/9
Elkhorn	4/27	8/21	none
Peterson	4/27	8/21	7/12-13; 8/6-14
Prairie	4/27	8/21	5/8; 5/27; 6/16-17; 6/27-28; 8/6-9
1992			
Bull	4/2	8/27	4/8, 4/16-22, 4/27, 4/29-5/2
Hunt	4/4	8/28	4/14, 4/16-20, 4/27-5/1, 5/16
0042	4/1	9/1	4/16-19, 4/28-30
Elkhorn	4/2	9/1	4/16-19, 4/30, 5/23
Peterson	3/31	9/1	4/16-20, 4/27, 4/29-5/1, 7/18, 7/21, 7/25, 7/30-8/6
Prairie	4/1	8/27	4/17-19, 4/27-5/1, 5/20
1993			
Bull	4/21	8/1	4/23-5/3, 5/22, 5/31-6/2, 6/10-12
Hunt	4/19	8/1	4/24-5/4, 5/8, 5/21-23, 5/31-6/2, 6/9-12, 6/14-16
0042	4/22	8/1	4/24-5/4, 5/9, 5/21, 6/9-12, 6/14-16
Elkhorn	4/20	8/1	4/27-5/3, 6/10-12
Peterson	4/22	8/1	4/24-5/3, 6/1, 6/9-12
Prairie	5/3[a]	8/1	5/21, 6/1, 6/9-15, 6/30[b]

[a] Trap installed 4/20, however, high water prevented operation.

[b] Trap not fishing due to low water.

APPENDIX B: Regression of the number of fry consumed and by coho smolts, cutthroat and steelhead trout of different lengths in the live box.

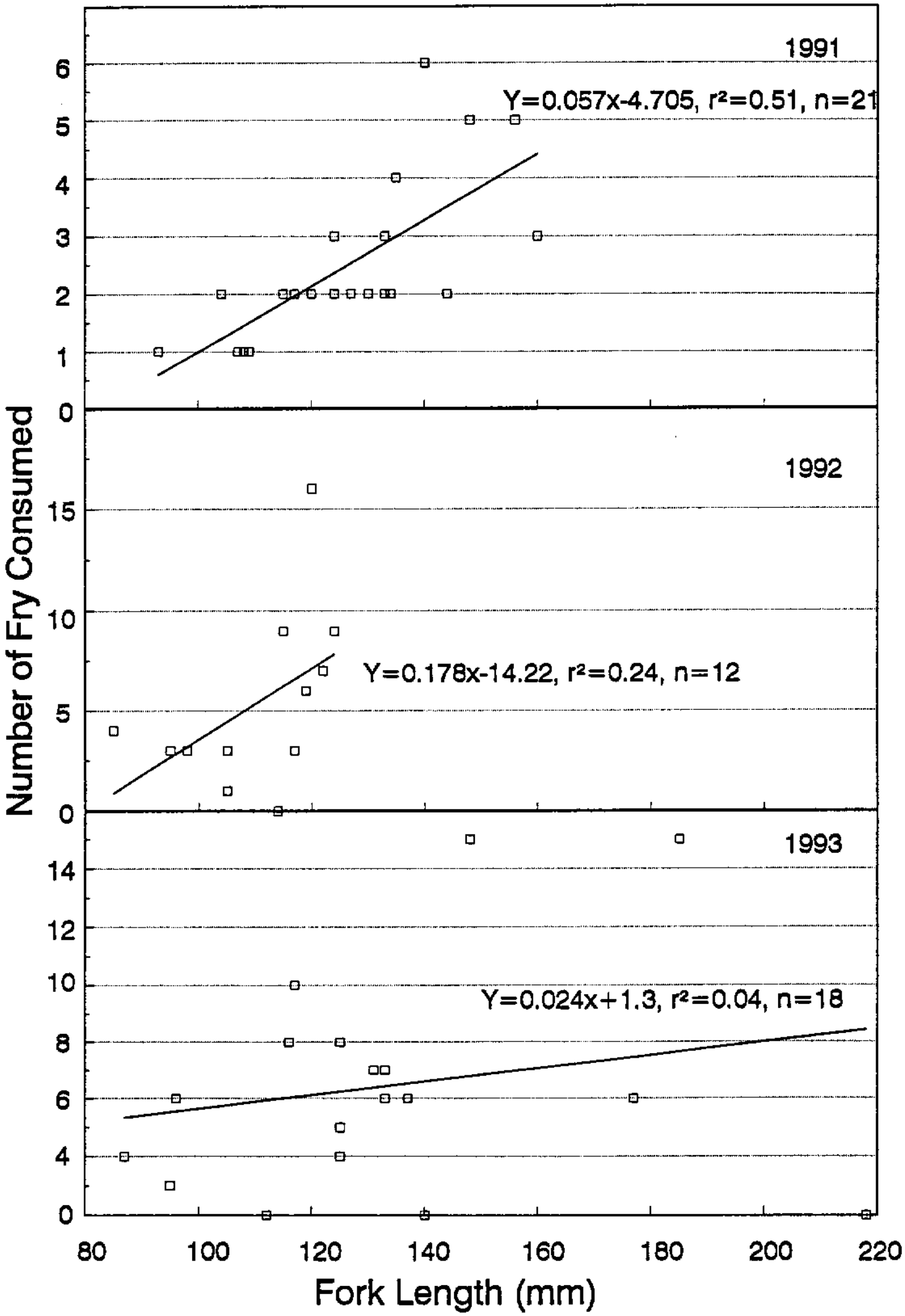

Figure B.1 Regression of the number of coho salmon fry consumed in the live-box by cutthroat trout, steelhead trout, and coho smolts of different length during 1991-1993.

APPENDIX C: **Emigration pattern of wild and hatchery-reared coho salmon fry and smolts and cutthroat and steelhead trout.**

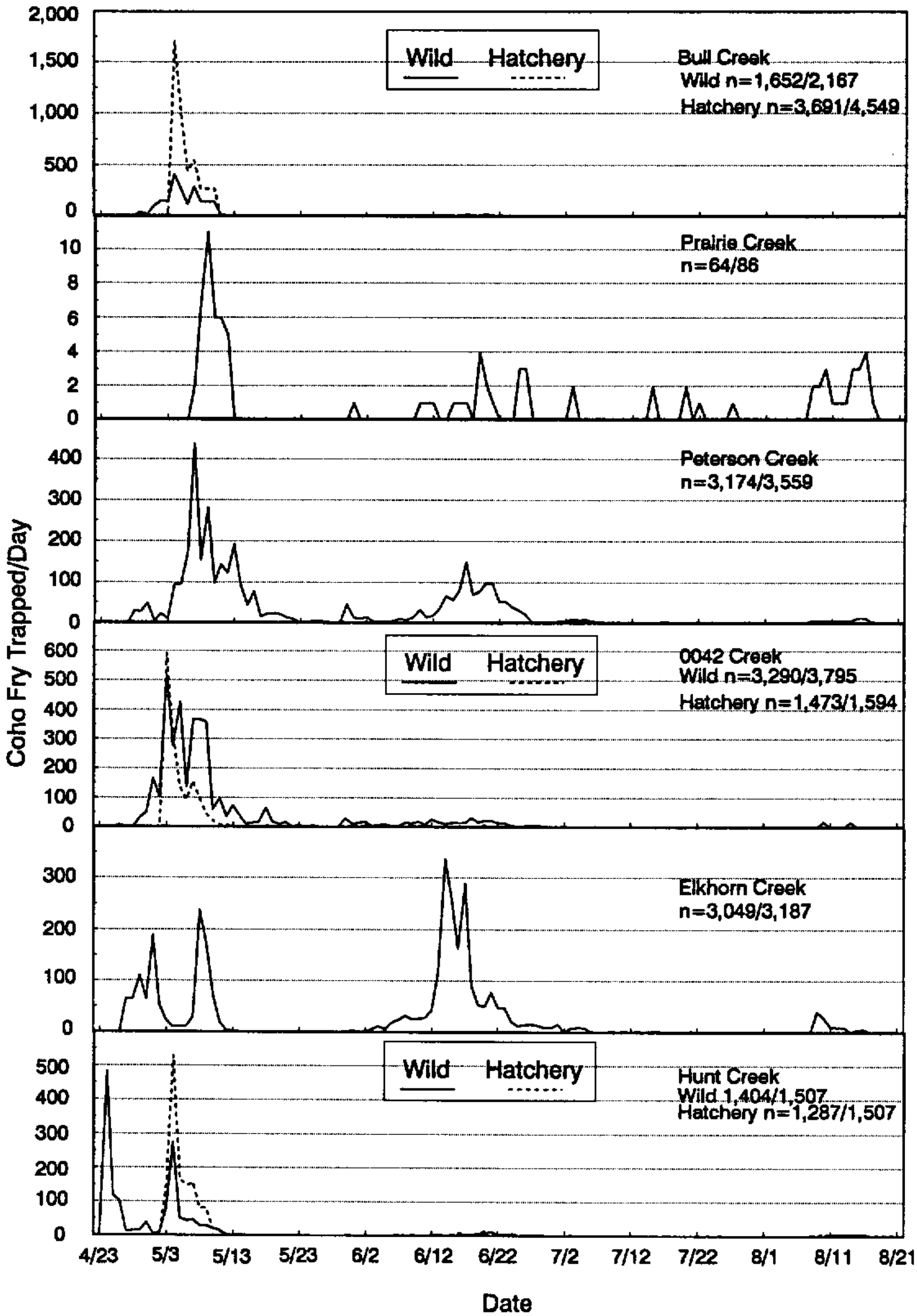

Figure C.1. Daily emigration of wild and hatchery-reared wild coho salmon fry from six tributaries of the Clearwater River, 1991. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

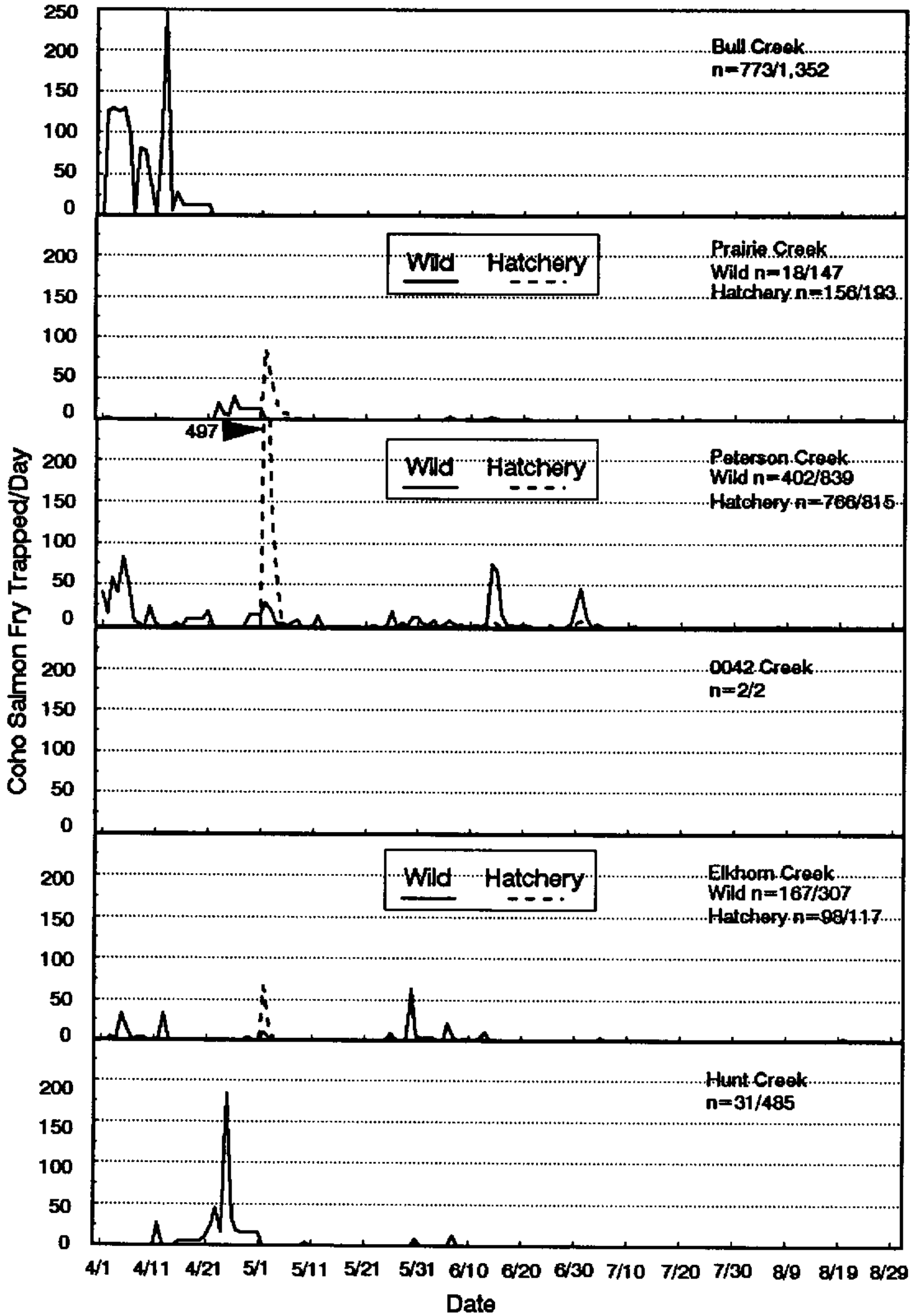

Figure C.2. Daily emigration of wild and hatchery-reared wild coho salmon fry from six tributaries of the Clearwater River, 1992. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

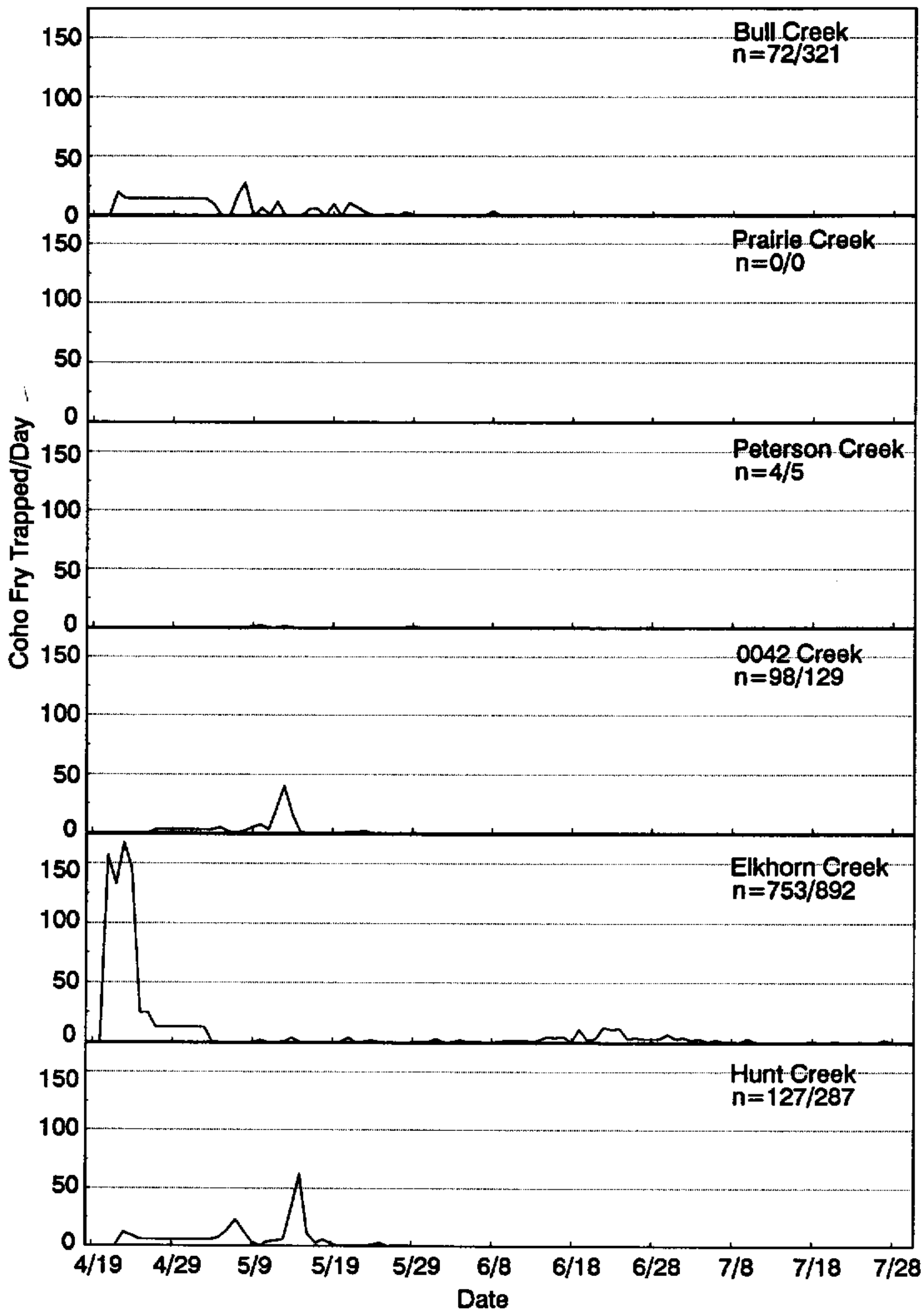

Figure C.3. Daily emigration of wild coho salmon fry from six tributaries of the Clearwater River, 1993. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

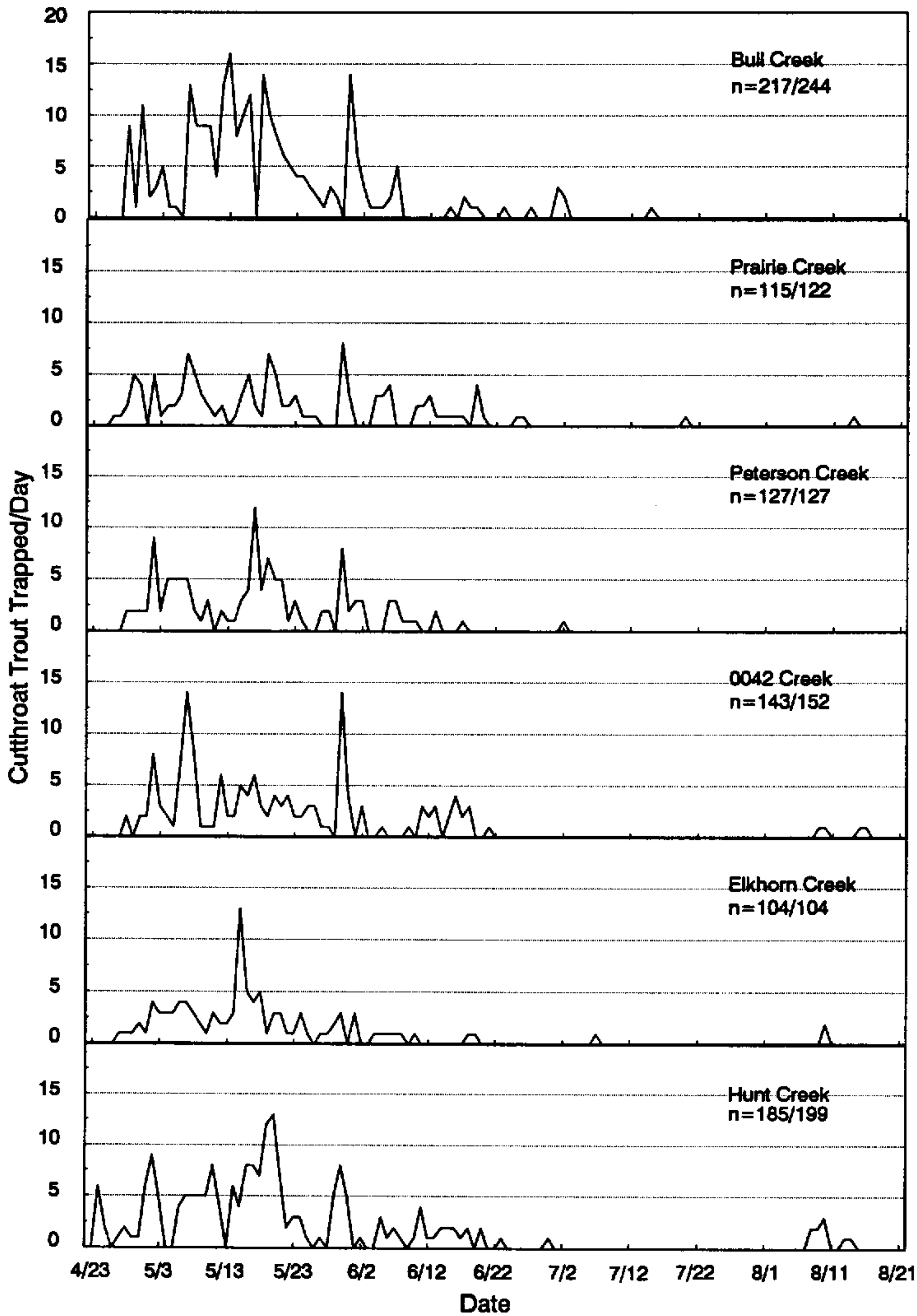

Figure C.4. Daily emigration of cutthroat trout from six tributaries of the Clearwater River, 1991. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

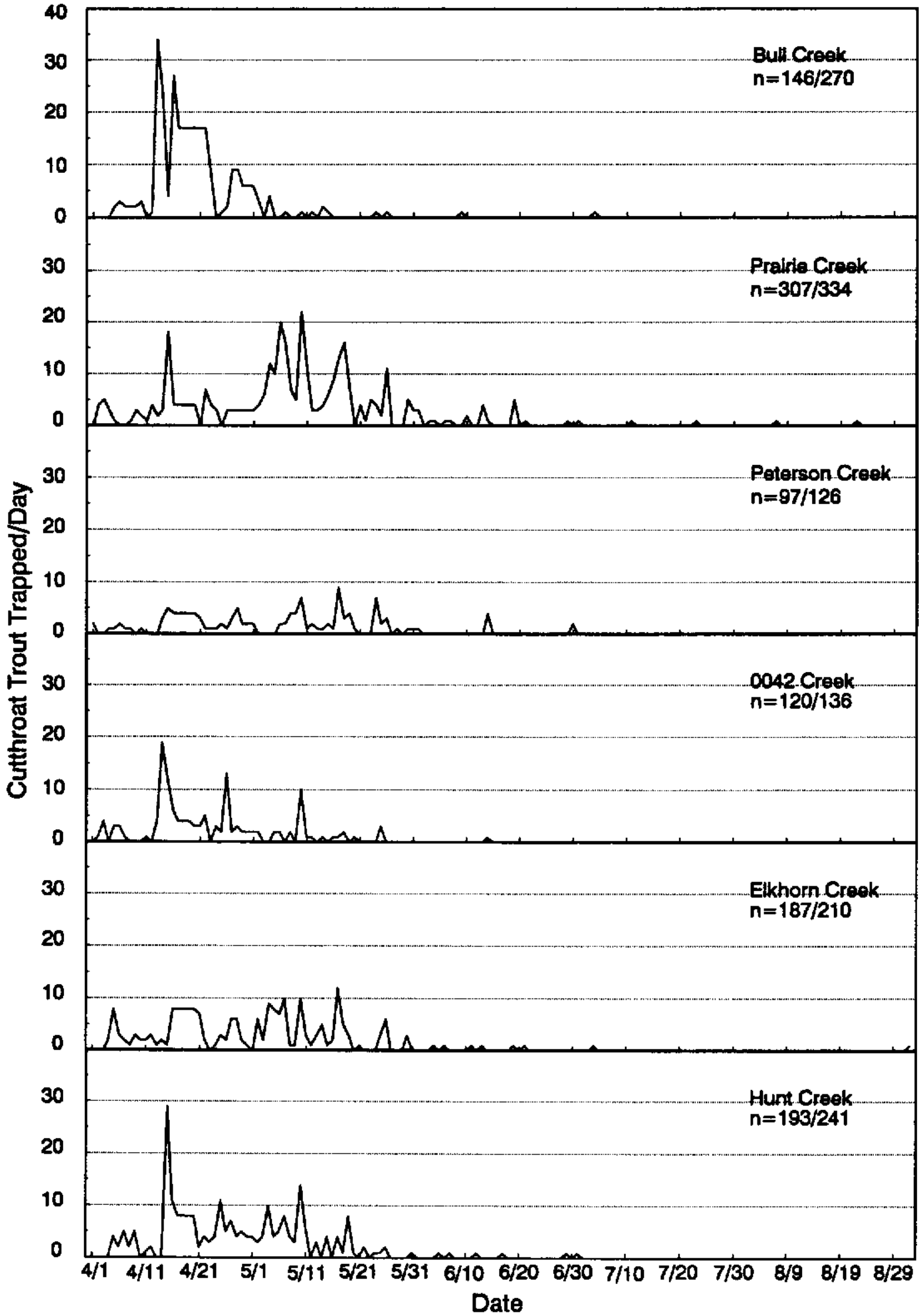

Figure C.5. Daily emigration of cutthroat trout from six tributaries of the Clearwater River, 1992. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

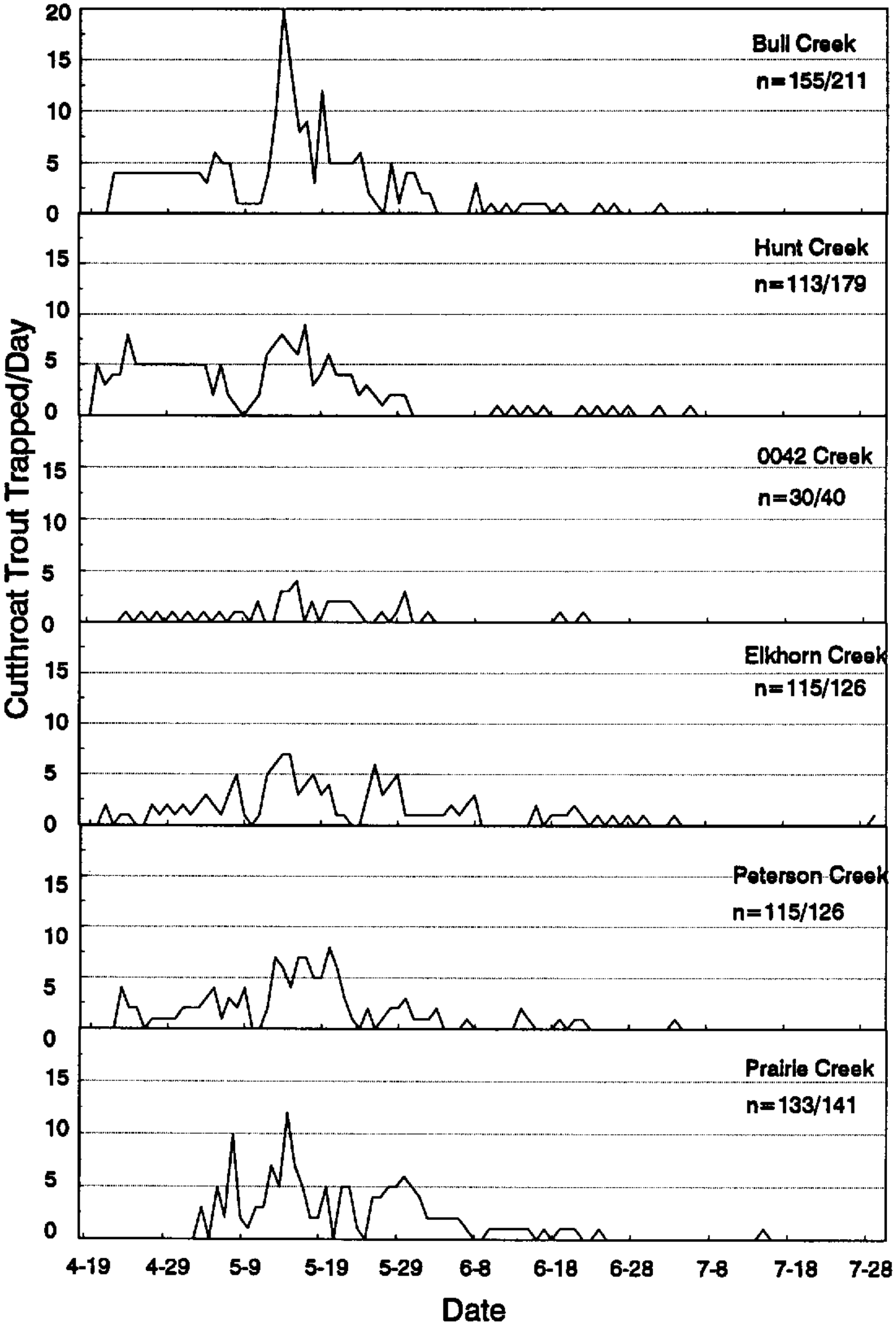

Figure C.6. Daily emigration of cutthroat trout from six tributaries of the Clearwater River, 1993. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

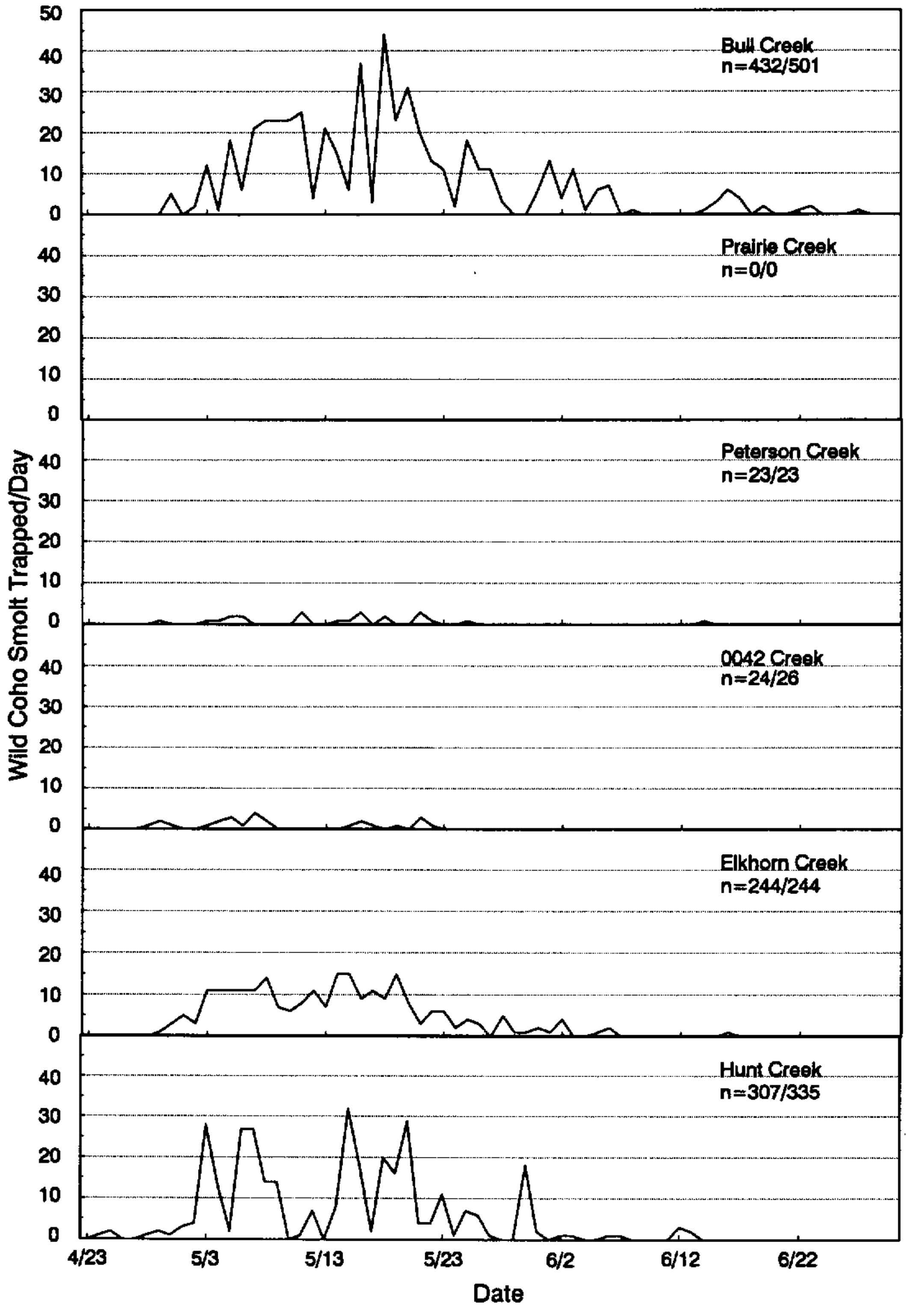

Figure C.7. Daily emigration of wild coho salmon smolts from six tributaries of the Clearwater River, 1991. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

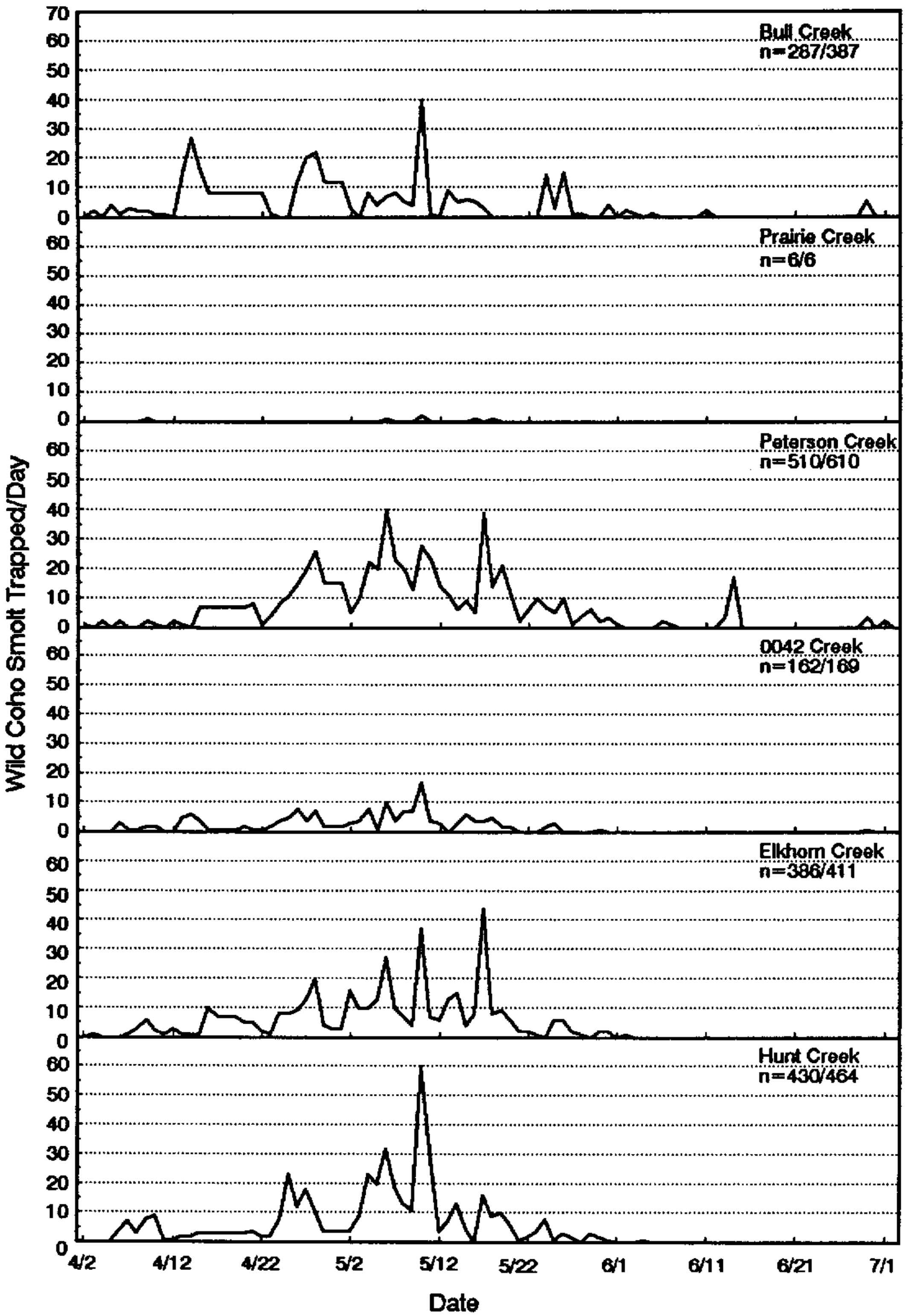

Figure C.8. Daily emigration of wild coho salmon smolts from six tributaries of the Clearwater River, 1992. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

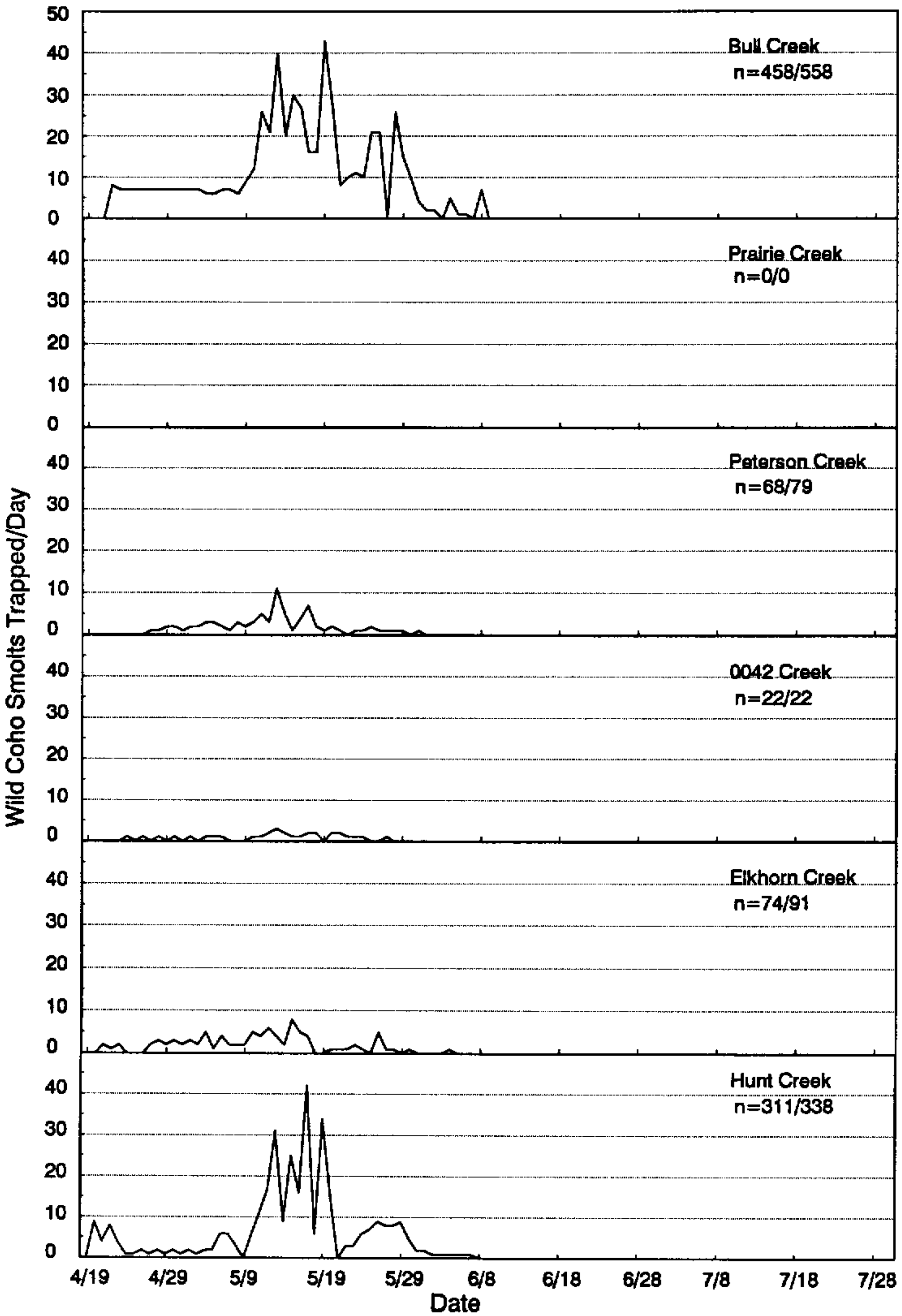

Figure C.9. Daily emigration of wild coho salmon smolts from six tributaries of the Clearwater River, 1993. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

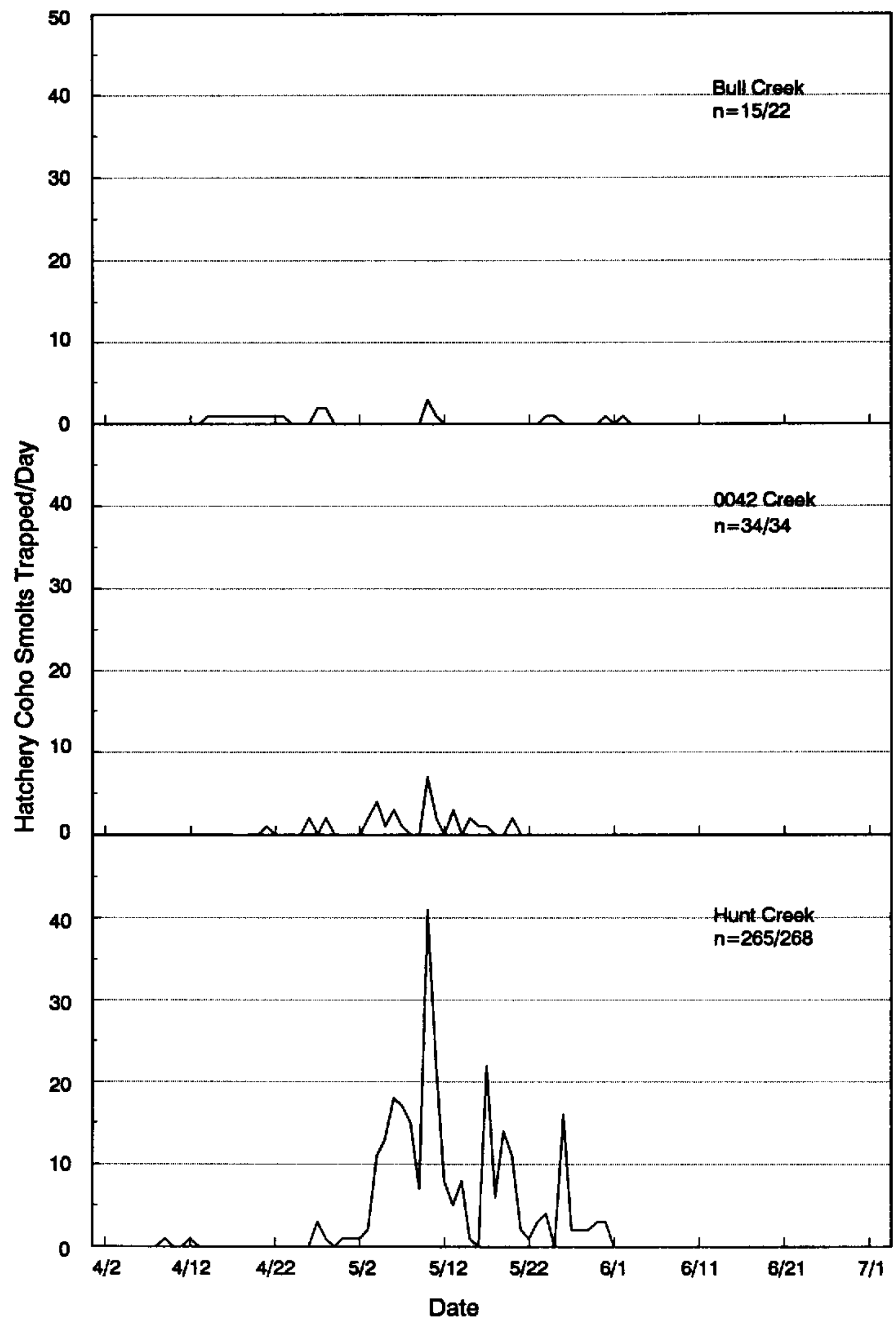

Figure C.10. Daily emigration of hatchery-reared wild coho salmon smolts from six tributaries of the Clearwater River, 1992. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

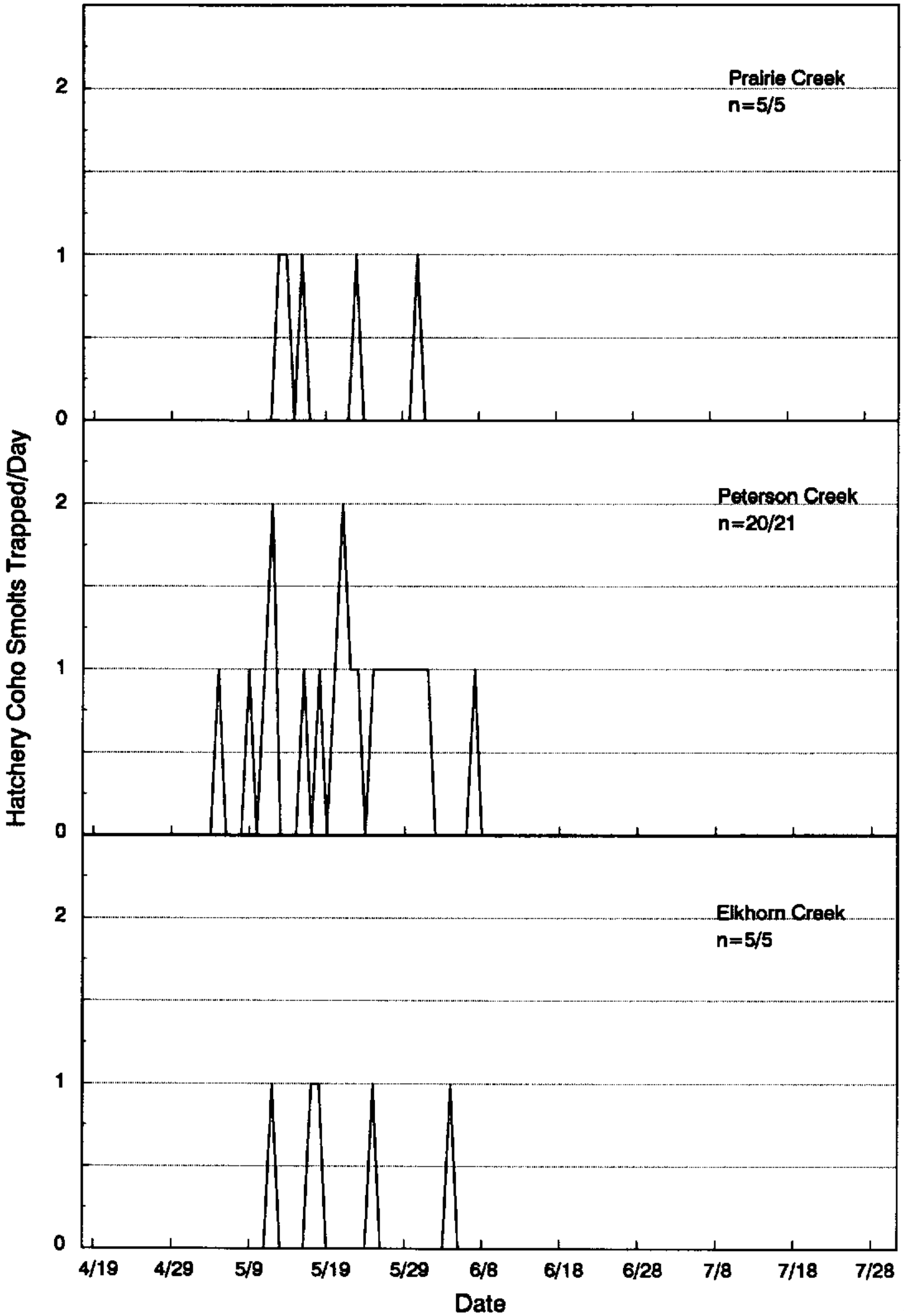

Figure C.11. Daily emigration of hatchery-reared wild coho salmon smolts from six tributaries of the Clearwater River, 1993. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

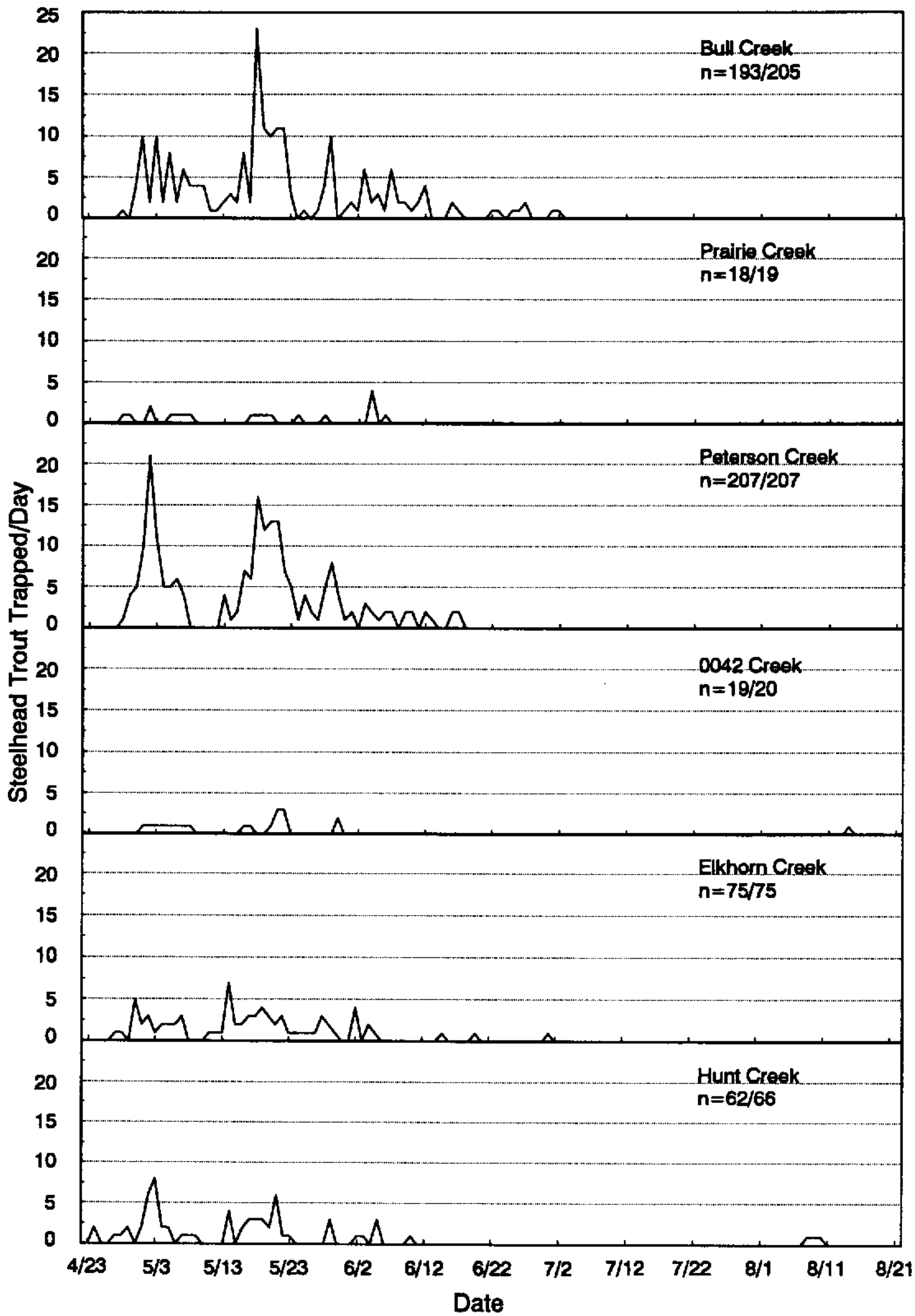

Figure C.12. Daily emigration of steelhead trout from six tributaries of the Clearwater River, 1991. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.

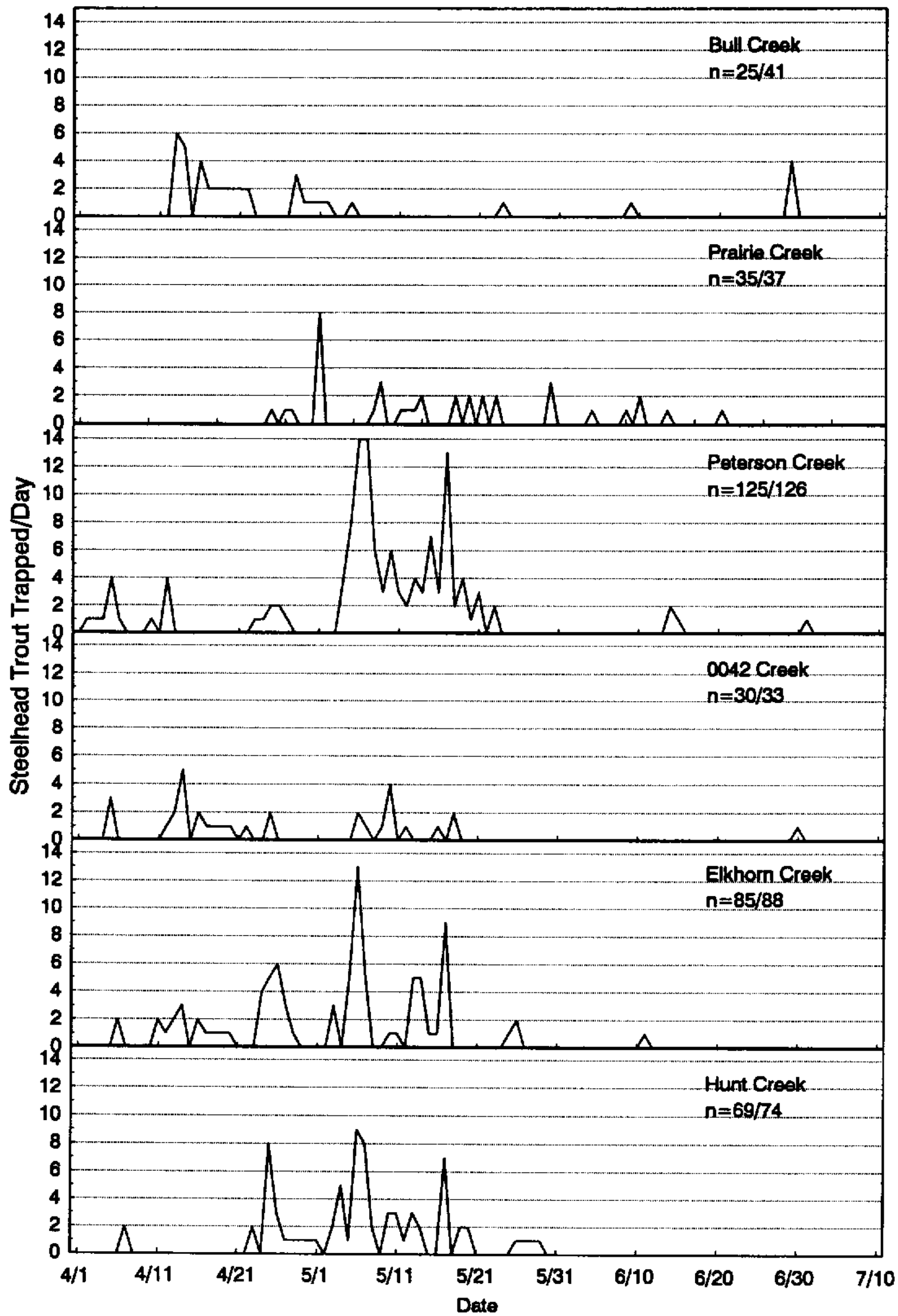

Figure C.13. Daily emigration of steelhead trout from six tributaries of the Clearwater River, 1992. Numbers (n) in the upper right hand corner of each graph represents actual catch/estimated number of emigrants.